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Memoirs of the Museum of Comparative Zoology

AT HARVARD COLLEGE.

VOL. XXVI. No. 1.

REPORTS ON THE SCIENTIFIC RESULTS OF THE EXPEDITION TO THE TROPICAL PACIFIC, IN CHARGE OF ALEXANDER AGASSIZ, BY THE U. S. FISH COMMISSION STEAMER "ALBATROSS," FROM AUGUST, 1899, TO MARCH, 1900, COMMANDER JEFFERSON F. MOSER, U.S.N., COMMANDING.

I.

PRELIMINARY REPORT

AND

LIST OF STATIONS.

BY ALEXANDER AGASSIZ.

WITH REMARKS ON THE DEEP-SEA DEPOSITS

BY SIR JOHN MURRAY.

WITH TWENTY-ONE CHARTS.

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CAMBRIDGE, U.S.A.:

Printed for the Museum.

JANUARY, 1902.

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I.

PRELIMINARY REPORT.

TOGETHER WITH A LIST OF THE STATIONS OCCUPIED BY THE "ALBATROSS."

BY ALEXANDER AGASSIZ.

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I ARRIVED at San Francisco on August 20th, and after consulting with Commander Moser we decided to leave on Wednesday, the 23d.[1] Everything shipped from the East had arrived with the exception of the tow-nets sent me by Dr. Krämer, and the deep-sea nets kindly ordered for me by Professor Chun of Leipzig. Captain Moser and I decided not to make any soundings nor do any deep-sea work until we had passed beyond the lines of soundings already run by the "Albatross" and "Thetis" between California and the Hawaiian Islands.

In latitude 31° 10′ N., and longitude 125° W., we made our first sounding in 1955 fathoms, about 320 miles from Point Conception, the nearest land. We occupied twenty-six stations until we reached the northern edge of the plateau from which rise the Marquesas Islands, having run from Station 1, a distance of 3800 miles, in a straight line.

At Station 2 the depth had increased to 2368 fathoms, the nearest land, Guadelupe Island, being about 450 miles, and Point Conception nearly 500 miles, distant. The depth gradually increased to 2628, 2740, 2810, 2881, 3003, and 3088 fathoms, the last in lat. 16° 38′ N., long. 136° 14′ W.,

[1] Explorations of the "Albatross" in the Pacific Ocean. [Extract from a letter to the Hon. George M. Bowers, U. S. Commissioner of Fish and Fisheries, Washington, D. C., dated Papeete Harbor, Tahiti Island, 30 September, 1899, on the trip of the "Albatross" from San Francisco to Papeete, by Alexander Agassiz.] Am. Jour. Sci., Fourth Series, Vol. IX., No. 49, January, 1900.

the deepest sounding we obtained thus far in the unexplored part of the Pacific through which we were passing. From that point the depths varied from 2883 to 2690 and 2776, diminishing to 2583, and gradually passing to 2440, 2463, and 2475 fathoms, until off the Marquesas, in lat. 7° 58′ S., long. 139° 08′ W., the depth became 2287 fathoms. It then passed to 1939, 1802, and 1040 fathoms in lat. 8° 41′ S., long. 139° 46′ W., Nukuhiva Island being about twenty miles distant. Between Nukuhiva and Hounanu Point, Ua-Huka Island, we obtained 830 fathoms, and five miles south of Nukuhiva 687 fathoms. When leaving Nukuhiva for the Paumotus we sounded in 1284 fathoms about nine miles south of that island. These soundings seem to show that this part of the Marquesas rises from a plateau having a depth of 2000 fathoms and about fifty miles in width, as at Station 29 we sounded in 1932 fathoms.

Between the Marquesas and the northwestern extremity of the Paumotus we occupied nine stations, the greatest depth on that line being 2700 fathoms at Station 31, in lat. 12° 20′ S., and long. 144° 15′ W. The depths varied between 2451 and 2527 fathoms, and diminished to 1208 fathoms off the west end of Ahii, and then to 706 fathoms when about sixteen miles N.E. off Avatoru Pass in Rangiroa atoll.

We developed to a certain extent the width of the Paumotu Group plateau by a line of soundings in continuation of the direction of Avatoru Pass, extending a little less than nine miles seaward, where we obtained a depth of 819 fathoms. Subsequently we ran a similar line normal to the south shore of the lagoon of Rangiroa, a distance of nearly twelve miles, into 897 fathoms.

Between Rangiroa and Tikehau, the next atoll to the westward, we obtained a depth of 1486 fathoms.

Between Tikehau and Matahiva six soundings were made, with a depth of 488 fathoms half a mile from shore, and a greatest depth of 850 fathoms six and one half miles from Tikehau. The slope approaching Matahiva is steeper than the Tikehau slope.

From Matahiva to Makatea (Aurora) Island, we made six soundings: from 624 fathoms about two and one half miles off shore to 581 fathoms about one and one eighth miles off the west side of the latter island, the

depths passing to 860, 1257, 1762, and the greatest depth being 2267 fathoms, then 2247, and rising more rapidly near Makatea to 581 fathoms.

Between Makatea and Tahiti we made eight soundings, beginning with 1363 fathoms, two miles off the southern end of Makatea, passing to 2238, 2363 (the greatest depth on that line), to 2224, 1930, 1585, 775, and finally 867 fathoms off Point Venus.

These make in all seventy-two soundings from our first station to Point Venus.

The deep basin developed by our soundings between lat. 24° 30′ N., and lat. 6° 25′ S., varying in depth from nearly 3100 fathoms to a little less than 2500 fathoms, is probably the western extension of a deep basin indicated by two soundings on the charts,[1] to the eastward of our line, in longitudes 125° and 120° W., and latitudes 9° and 11° N., one of over 3100 fathoms, the other of more than 2550 fathoms, showing this part of the Pacific to be of considerable depth and to form a uniformly deep basin of great extent, continuing westward probably, judging from the soundings, for a long distance.

I would propose, in accordance with the practice adopted for naming such well-defined basins of the ocean, that this large depression of the Central Pacific, extending for nearly thirty degrees of latitude, be named Moser Basin.

In naming the "Moser" Basin I am following the practice adopted by the "Challenger" and Coast Survey, of naming after naval officers or the ships they commanded prominent hydrographic features. Dr. Neumayer in 1882, in the Atlas of the Atlantic Ocean issued by the German Marine Observatory, was the first to object to this system of nomenclature, on the ground of the confusion likely to arise from the adoption of personal names when applied to ridges, basins, deeps, and plateaus in the different oceanic realms. He proposed a strictly geographical nomenclature, which ignored the personal names given in the earlier bathymetrical charts; and the same principle was carried out in the Atlas of the Indian and Pacific Oceans subsequently published by the German Marine Observatory. Finally, Professor Supan, in his article on "Die Bodenform des Welt-

[1] H. O. Chart, No. 527.

meeres,"[1] has followed the same principle, and has in no way recognized the names which appear on the "Challenger" bathymetrical chart or the earlier charts of Petermann, issued in 1877, or in the charts issued by the U. S. Coast and Geodetic Survey. In order to prevent a possible future confusion, the Germans have deliberately created it; for Professor Supan objects on "national grounds" to Sir John Murray's proceeding of "tagging the oceans as if they were Anglo-Saxon dominions," and insists that such a proceeding "can never receive general recognition." Professor Supan considers the Anglo-Saxon method "as impracticable because in the future it may burden the memory of the school children of the next generation." If we are to have a remodelling of the oceanic bathymetrical nomenclature, it seems as if we were attempting it with very insufficient data, at least as far as the Pacific is concerned. Professor Supan himself has called attention to the fact that the bottom of the Pacific Ocean is far less uniform in depth than would appear from the earlier charts; and certainly the great blank spaces left between the lines of soundings make it sufficiently clear how tentative all our attempts to chart the depths of the Pacific must be for some time to come. Of course, I do not in any way wish to object to a more strict limitation of the hydrographic terms proposed by Dr. Supan, many of which have naturally in the earlier days of deep-sea explorations been applied somewhat vaguely. In the meantime basins, deeps, and ridges, such as are sketched and named on the earlier charts, will gradually disappear as subsequent explorations show them to be connected; others again will be subdivided as our knowledge of the depths of the oceans becomes more accurate.

No geographer has as yet attempted for land names to make such a sweeping reform as that proposed by the Germans. It is true that the great oceanic realms are common property, and have not as yet, like the islands scattered in the Pacific, become included in regions of English, French, German, or American influence. But it will appear to an Anglo-Saxon as natural, from a national standpoint, to adhere to his nomenclature as it seems important to the German, for the same reason, to adopt a different system. To a naturalist accustomed to have such questions settled for

[1] Petermann's Mitteil., Bd. 45, 1899, p. 177.

1 Station 13 Lat. 1° " Long. 157° " " " "

2-4 " 173 " 18° 55′ S. " 146° 32′ W ; "

5-6 " 2 " 28° 23′ N. " 126° 57′ W. , 2368 "

him on the principle of priority, it seems unjustifiable to cancel a name given to an oceanic ridge, or to a great basin or deep, and to substitute another because it agrees with the principles of the reformer.

Professor Supan anticipates that all maritime nations will attempt in the future to perpetuate the names of their exploring ships and their captains, and thus introduce endless confusion. But certainly the confusion can be no greater than it is in the interior of Africa, where each explorer, according to his nationality, has given the names of his eminent countrymen to the physical features of the country he traversed.

The nomenclature of the Arctic and Antarctic regions, depending absolutely upon the national geographical system, if I may so call it, is perhaps the most obvious example of the approval which civilized nations have given to the system which perpetuates the names of the hardy explorers and of the ships they commanded when pushing their way towards the poles. Bold indeed would be the man to attempt on "national grounds" to reform the names associated with so many heroic voyages. I do not mean by this in any way to compare the hardships of the Arctic voyages with those explorations which are laid in the pleasant paths of the tropics, and finally can only suggest that school children may perhaps learn a little interesting history if geographical names do not everywhere replace personal ones.

The character of the bottom of the Moser basin is most interesting. The haul of the trawl made at Station 2, lat. 28° 23′ N., long. 126° 57′ W., brought up the bag full of red clay and manganese nodules, with Tertiary sharks' teeth and cetacean ear-bones; and at nearly all our stations we had indications of the existence of manganese nodules. At Station 13, in 2690 fathoms, lat. 9° 57′ N., long. 137° 47′ W., we again obtained a fine trawl-haul of manganese nodules and red clay; there must have been at least enough to fill a forty-gallon barrel.

The nodules in our first haul were either slabs from six to eighteen inches in length and four to six inches in thickness, or small nodules ranging in size from that of a walnut to a lentil or less, while those brought up at Station 13 consisted mainly of nodules looking like mammillated cannon-balls, varying from four and a half to over six inches in diameter, the

largest being six and one half inches. We again brought up manganese nodules at the equator in about longitude 138° W., and subsequently — until within sight of Tahiti — we occasionally trawled manganese nodules.

As had been noticed by Sir John Murray in the "Challenger," these manganese nodules occur in a part of the Pacific most distant from continental areas. Our experience has been similar to that of the "Challenger," only I am inclined to think that these nodules range over a far more extensive area of the Central Pacific than had been supposed, and that this peculiar manganese-nodule bottom characterizes a great portion of the deep parts of the Central Pacific, where it cannot be affected by the deposition of Globigerinæ, Pteropods, or telluric ooze, in the region characterized also by red-clay deposits. For in the track of the great equatorial currents there occur deposits of Globigerina ooze in over 2400 fathoms for a distance of over 300 miles in latitude.

We also found manganese nodules south of the Marquesas; at Station 31, when in 2700 fathoms, we obtained perhaps the finest specimens of red clay from any of our soundings. As we approached the western Paumotus, upon the north side of the plateau from which they rise, Globigerina ooze passed gradually to Pteropod ooze, then to fine and coarse coral-sand. In the channel south of the Paumotus to Tahiti the coral sand passed to volcanic sand mixed with Globigerinæ in the deepest parts of the line, and toward Tahiti passed to volcanic mud mixed with Globigerinæ, next to fine volcanic sand, and finally, at the last sounding, off Point Venus, to coarse volcanic sand.

We made a few hauls of the trawl on our way, but owing to the great distance we had to steam between San Francisco and the Marquesas (3800 miles) we could not, of course, devote much time either to trawling or to making tows at intermediate depths. Still, the hauls we made with the trawl were most interesting, and confirmed what other deep-sea expeditions have recognized: that at great depths, at considerable distances from land and away from any great oceanic current, there is comparatively little animal life to be found. Where manganese nodules were found in abundance the hauls were specially poor, a few deep-sea Holothurians and Ophiurans, and some small Actiniæ which had attached themselves to the

nodules, with a few other invertebrates, seemed to be all that lived at these great depths, in 2500 to 2900 fathoms, far away — say from 700 to 1000 miles — from the nearest land.

The bottom temperatures of the deep Moser basin varied between 34.6° at 2628 and 2740 fathoms, to 35.2° at 2440 fathoms, and 35° at 2475 fathoms, about 175 miles from the Marquesas. At Station 23, off the Marquesas, in 1802 fathoms, the temperature was 35.5°.

Owing to the failure of many of our deep-sea thermometers, we were not able to make any satisfactory serial-temperature observations. At Station 11, lat. 14° 38′ N., long. 136° 44′ W., in 2646 fathoms, we obtained:

79° at surface.	48.9° at 200 fathoms.
78.7° " 50 fathoms[1]	44.1° " 300 "
55.9° " 100 "	39.9° " 700 "

These temperatures are somewhat higher than those obtained by the "Challenger" in similar latitudes on their line to the westward of ours between the Hawaiian Islands and Tahiti. At Tahiti a temperature of 40° is found to vary between 500 and 600 fathoms, off Hawaii a temperature of 48° obtains in 224 fathoms, at Hilo 40° was found in 400 fathoms, much colder than on the eastern lines.

The temperatures of the bottom between the Marquesas and Paumotus were 34.9° at 1932 fathoms, 35° at 2456 fathoms and 2451 fathoms, and 35.1° at 2527 fathoms.

We did not take any bottom temperatures between the Paumotus and Tahiti.

Our deep-sea nets not having reached San Francisco at the time we sailed, we limited our pelagic work to surface hauls, of which we generally made one in the morning and one in the evening, and whenever practicable, some hauls with the open tow-nets at depths varying between 100 and 350 fathoms. The results of these hauls were very satisfactory. The

[1] Off shore off San Francisco the "Albatross" observed in line San Francisco to Hawaiian Islands.

Fathoms		Fathoms.	
352	53.5°	1122	35.5°
618	39°	1597	35°
867	37°	2594	34.9°

collection of surface animals is quite extensive, and many interesting forms were obtained. As regards the deeper hauls, they only confirm what has been my experience on former expeditions, that beyond 300 to 350 fathoms very little animal life is found, and in the belt above 300 fathoms the greater number of many so-called deep-sea Crustaceans and deep-sea fishes were obtained. I may mention that we obtained Pelagothuria at about 100 fathoms from the surface.

We trawled at Station 10 in 3088 fathoms. Unfortunately, the trawl was not successful, and we simply hauled the bag through over 3000 fathoms without bringing up a single deep-sea animal from intermediate depths which we did not obtain quite near the surface — at less than 300 fathoms. I may mention here that the experience of the "Valdivia" shows, from the preliminary reports published by Professor Chun,[1] that pelagic algæ do not extend to beyond about 150 fathoms. Although he also states that animal life is found at all depths from the surface to the bottom, yet he states that beyond 800 meters it diminishes *very rapidly;* Professor Chun does not state whether this diminution is more rapid away from land than near continental areas, both of which conditions I had called especial attention to in my Preliminary Report on the "Albatross" expedition of 1891, while using the Tanner net in the Gulf of California.[2] Mr. George Murray has criticised the action of the Tanner deep-sea net, and condemns its results, suggesting that the bottom net had always closed some time after being sent down.[3] I need not now discuss that subject, but will only refer him to the report of the "Albatross," in which he will find the closed part of the net to have on several occasions brought up (when I expected it to do so) specimens from over 600 fathoms from immediately above the bottom, or samples of the bottom from near 1700 fathoms while attempting to tow immediately above that depth. I ought, in justice to him, to state that I omitted to mention that we secured the loops by twine to the detacher to insure their dropping only when the

[1] Die Deutsche Tiefsee Expedition 1898–99. Zeits. d. Gesell. für Erdkunde zu Berlin, 1899, XXXIV., Heft 2.

[2] Bull. M. C. Z., 1892, Vol. XXIII., No. 1, pp. 40, 45.

[3] George Murray. Exploration of the intermediate depths of the ocean. Geog. Mag., XIII., No. 2, February, 1899, p. 152.

messenger reached the detacher, and that the hooks of the detacher were lengthened very considerably above the dimensions figured in my Preliminary Report on the "Albatross" expedition of 1891. I might add that we made a number of trials near the surface to see the action of the Tanner net under all conditions of position and speed, and I can only assume that Mr. Murray, having no experience, did not handle his net properly, or that it was not properly balanced. I may also add that Captain Tanner used his modified net subsequently in the "Albatross," while running a line of soundings from San Francisco to the Hawaiian Islands, in from 100 to 350 fathoms from the surface, at considerable distances from the islands and the mainland, and also in Alaskan waters, and always with the results we had obtained before. The closed bag, when towing at 100 fathoms below the surface, always brought up a mass of pelagic animals living at about that depth, while when tried at 300–350 fathoms it brought up little or nothing. There is nothing in Captain Tanner's experience,[1] — who, as commander of the "Albatross" from 1883 until 1894, has had a longer service in deep-sea explorations than any other individual, — or mine, to indicate why the net should act well at 100 fathoms and not well at 300 fathoms or more, as suggested by Mr. Murray.

Subsequently, during the winter of 1893–94 when off the northern coast of Cuba, during my cruise in the "Wild Duck"[2] I had occasion again to use the modified deep-sea self-closing Tanner net, and found no reason to change the views regarding the general bathymetrical distribution of pelagic life I had expressed in my Preliminary Report on the Results of the "Albatross" Expedition of 1891.

In the winter of 1897–98 I also made a number of hauls with the deep-sea self-closing Tanner net at several points in Fiji, the results of which will be found in my Report on the Islands and Coral Reefs of Fiji.[3]

As long as we have no better acquaintance with the surface fauna of the great oceans than we now possess, it is idle from the few hauls which have made us familiar with some of the denizens of a bathymetric belt

[1] Z. L. Tanner. On the appliances for collecting pelagic organisms. Bull. U. S. Fish Commission, Vol. XIV., 1895, p. 143.

[2] Bull. M. C. Z., XXVI., No. 1, 1894, p. 7.

[3] Bull. M. C. Z., Vol. XXXII., 1899, p. 14.

extending from the surface down to, say 300 fathoms, at the outside, to undertake to classify them into distinct series extending from the surface to great depths. What is still needed is a careful exploration of the bathymetrical range of the pelagic fauna on a line extending far out to sea from a continental slope into great depths, and a similar line along a great oceanic current far from any disturbing element such as an archipelago or submarine plateaus.

If we knew all the species of the so-called pelagic belt it would be a different thing; but when the peculiar fish with pedunculated eyes which Chun calls a deep-sea fish, and specially characteristic of intermediate depths, is found by us at 100 fathoms, this, as well as the many other fishes and so-called deep-sea Crustacea, Holothurians, Ascidians, and Medusæ which we caught at or about the 100-fathom line in this and in my former expeditions, plainly shows that as yet we are very far from knowing the species which inhabit the belt between 100 fathoms or more and the surface.[1] No deep-sea expedition using better and newer appliances has as yet failed to bring up within these limits some so-called new deep-sea species if they happen to have brought it up when dropping the net in greater depths, while the next explorer again brings it up from inside the 100-fathom line. (See note.) I still reiterate that near the bottom, and some distance above it, a certain number of so-called pelagic species undoubtedly live, as well as in proximity to the continental slopes; but that is no criterion of the mode of distribution of pelagic life at sea far away from continental areas. When thus caught

Note. — I may mention among the Fishes: Collettia, Scopelus, Myctophum, Argyropelecus, Polyipnus, Plectromus, Paralepis, Stomias, Malacosteus, Eustomias, Melamphaës, Trachichthys, Sternoptyx, Cyclothone, Gonostoma, Notoscopelus, Lampanyctus, Cyema, Caulolepis, Hoplostethus, Chaunax, and Melanocetus. Among the Crustacea: Gnathophausia, Thysanopoda, Bentheuphausia, Willemœsia, Stylocheiron, Nematoscelis, Euphausia, Syriella, Nyctiphanes, Sergestes, Benthœcetes. The remarkable Ascidian Octacnemus. The pelagic Holothurian Pelagothuria, and the greater number of the so-called deep-sea Medusæ: Atolla, Periphylla, and Nauphanta, as well as a number of so-called deep-sea Siphonophores, Bathyphysa, and the like, which are caught by the wire rope.

[1] Die Deutsche Tiefsee Expedition 1898–99, Berlin, 1899, p. 54. Zeits. d. Gesell. f. Erdkunde zu Berlin, 1899, XXIV., Heft 2.

near the land it teaches us nothing of their bathymetrical range, as they may occasionally wander off miles by being carried seaward by currents and drop off into deep water along continental slopes.

Unfortunately, the marked paucity of pelagic animal life in the Pacific makes it well-nigh impossible to obtain data for their bathymetrical distribution with the limited information we have.

On our way to Tahiti from the Marquesas we stopped a few days to examine the westernmost atolls of the Paumotus. After striking Ahii we made for Rangiroa, the largest atoll of the Paumotu Group. Skirting the northern shore from a point a little west of Tiputa Pass, we entered the lagoon through Avatoru Pass, anchoring off the village. This pass is quite narrow, with a strong current running out the greater part of the time, especially in easterly winds. It varies in depth between nine and ten fathoms, shoaling near the inner entrance to about three and one half fathoms, and deepening again to six or seven fathoms, and gradually passing into fifteen to seventeen fathoms, which is the average depth of the lagoon from Avatoru Pass across to the south or weather shore, a distance of about thirteen miles.

We made an examination of the northern side of the lagoon between Avatoru and Tiputa Passes. The lagoon beach of the northern shore is quite steep, and is composed of moderately coarse broken coral sand at the base, and of larger fragments of corals along the upper face, which is about 5 to 6 feet above high-water mark. These coral fragments are derived in part from the corals living on the lagoon face of the northern shore, and in part of fragments broken by the waves from somewhat below the low-water mark. The ledge which underlies the beach crops out at many places on the lagoon side of the northern land-rim; we traced it also along the shores of Avatoru Pass, and specially about half-way between Avatoru and Tiputa Passes across the narrow northern land-rim. It crops out also at various points between these passes in the narrow cuts which divide this part of the northern land-rim of the lagoon into a number of smaller islands. These secondary passes leave exposed the underlying ledge, full of fossil corals. In some cases these secondary passes leave a clear channel extending across from the lagoon to the northern

side, through which water flows at high or half tide. In other cases the cuts are silted up with coral sand blown in from the lagoon side. In others, the cut is shut off by a high sand-bank, or a bank composed of broken fragments of corals, leaving access to the water from the northern shore only; and finally the cuts are also shut off on the northern side by sand and broken coral banks, the extension of the north shore outer beach leaving a depression which at first is filled with salt-water and gradually silted up both from the lagoon side and the sea-side, and forms the typical north-shore land-rim of the lagoon. This building up of the land-rim of the Paumotu atolls by the accumulation of sand both from the lagoon side and the sea face, is very characteristic of the atolls of that group. It is a feature which I have not seen so marked in any other coral-reef district.

On the lagoon side the slope from the beach is very gradual into sixteen and seventeen fathoms, and corals appear to flourish on the lagoon slope to six or eight fathoms only, in some cases consisting of Madrepores, in others of Porites or of Astræans, and Pocillopores. The corals could be seen over the floor of the Avatoru passage down to from nine to ten fathoms; and on the sea face Pocillopores covered the outer edge of the shore platform. This platform is from 200 to 250 feet wide, and was formed by the planing off of the seaward extension of the ledge cropping out in the cuts.

It became very evident, after we had examined the south shore of the lagoon, that the ledge underlying the north shore is the remnant of a bed of Tertiary coralliferous limestone, which at one time covered the greater part of the area of the lagoon, portions of which may have been elevated to a considerable height. This limestone was gradually denuded and eroded to the level of the sea. Passages were formed on its outside edge, allowing the sea access to the inner parts of the lagoon limestone flat. This began to cut away the inner portions of the elevated limestone, forming large sounds, as in the case of Fiji atolls, and leaving finally on the south side only a flat strip of perhaps 2500 to 3000 feet in width, which has gradually been further eroded on the lagoon side and also on the sea face, to leave only a narrow strip of land about 1000 feet in width and perhaps ten to fourteen feet in height, the material for this land hav-

ing come from the disintegration of the ledge of Tertiary limestone, both on the sea face and the lagoon side.

There exist in the lagoon a number of small islets which also consist of this same Tertiary limestone in process of disintegration and transformation to coral-sand islets. They are the islets at the lagoon side of both Avatoru and Tiputa Passes, the two islets which we found along our line of soundings across the lagoon, the one about four and one half miles from the north side of the lagoon, and the other about the same distance from the south shore. I am told that the eastern extremity of the lagoon is filled with islets and heads consisting of the same limestone rock so characteristic of the north and south shores of the lagoon.

The underlying ledge is not the remnant of a modern reef; its character is identical with that of the elevated limestones of Fiji, which are of Tertiary age, and the rock is in every respect the same as that I observed on many of the elevated islands of Fiji. The atoll of Rangiroa is in a stage of denudation and erosion very similar to that of Ngele Levu, in Fiji, only in Ngele Levu the elevated limestone attains a height of about sixty feet. Our visit to the southern land-rim of the lagoon, both on the lagoon side and on the sea face, left us no doubt regarding the character of the underlying ledge of the north shore. As soon as the south-shore land was sufficiently near, as seen from the lagoon side, for us to distinguish its character, we could see that the entire shore line was formed of a high ledge of limestone, honeycombed, pitted, and eroded by atmospheric agencies, and undercut by the action of the waves both on the lagoon side and on the sea face. The great rollers of the weather side broke through between the columnar masses of the ledge into the lagoon, and as far as the eye could reach there extended a more or less continuous wall (which is described by Dana[1] as he saw it while sailing by in the "Vincennes"). But in addition to this we found, on landing, this wall to be the sea face of the islands and islets which dot the weather side for the greater part of its length on the southwestern part of the lagoon.

These islands and islets of the weather land-rim are entirely composed of coral sand and coral fragments, formed from the disintegration of the

[1] Corals and Coral Islands, 3d ed., 1890, p. 369.

extension of the elevated ledge toward the inside of the lagoon to a distance of about one and one half to two miles; and along this very gradual inner slope of the islands forming the southern edge of Rangiroa, corals grow profusely down to six or seven fathoms of water, when the bottom runs into hard coralline bottom, similar to that found on all the soundings taken across the lagoon.

The width of the larger islands of the weather land-rim is about 1000 to 1200 feet; the smaller islands and islets are less, some of the latter forming in reality mere sand buttresses at right angles to the great limestone ledge which flanks them all on the sea face and connects them on the weather side as if by a great wall, more or less broken, and partly shuts off the communication of the interior of the lagoon with the sea on that side.

The passages between the islands and islets illustrate well, only on a larger scale, the formation of the cuts, more or less silted up, which were observed on the northern face of the lagoon. Some of these passages are dry at low-water, others are partly filled by tide pools, others are entirely silted up by lagoon sand, only they are lower than the sand-blown land of the islands on either side of it.

Crossing over to the weather side of the southern land rim of Rangiroa in one of the passages between two of the islands, we came upon the coralliferous limestone ledge, from twelve to fourteen feet high and about forty to fifty feet wide at the top, which formed the sea face of the islands and islets, and extended far to the westward as a great stone wall more or less broken into distinct parts. We found this ledge to consist of elevated limestone as hard as calcite, full of corals, honeycombed and pitted, and worn into countless spires and spurs, and needles and blocks of all sizes and shapes, separated by deep crevasses or pot-holes recalling a similar scene in Ngele Levu on the windward end of the lagoon. In the passages the parts of the ledge which had not been eroded extended as wide buttresses, gradually diminishing in height till they formed a part of the lagoon flat and extended out into the lagoon below the recent beach-rock which covered it in short stretches.

The sea-face slope of the elevated ledge was quite steep, but otherwise similar to the lagoon slope, and its upper surface weathered by atmospheric

and aqueous agencies into all possible shapes such as I have mentioned. The slope passed into the shore platform, which was shaved down, as it were, to a general level surface. On the outer edge, within the line of the breakers, were growing Pocillopores and Nullipores in great abundance. This reef flat or shore platform, as well as the reef platform of the north shore, was strewn here and there with huge masses of the ledge of elevated reef-rock torn from its outer edge. Similar rocks and bowlders occur on the lagoon side of the islands forming the outer land-rim of Rangiroa; they are either torn off from the lagoon face of the outcropping ledge, or are outlying parts of the ledge which have remained in place and have not been planed down to the base level of the reef.

The amount of water which is forced into such a lagoon as Rangiroa is something colossal, and when we observe that there are but a small number of passages through which it can find its way out again on the leeward side, it is not surprising that we should meet with such powerful currents, seven to eight knots in several cases, sweeping out of the passages on the lee side.

The islands and islets of Rangiroa are fairly well covered with low trees and shrubs and large groves of palm trees.

The atolls of Tikehau and Matahiva, which we also examined, present no features which we did not meet in Rangiroa. The first-named atoll shows the same method of formation of the land-rim by material piled up both from the lagoon side and the sea face,—material derived from the disintegration of the underlying Tertiary limestone, which crops out here and there along the sea face and the inner shores of the lagoon, or forms across the southwest face of the lagoon an irregular, disconnected part of the ring of islands and islets encircling that end of the lagoon. These islets and islands are more or less connected by fragments of the elevated limestone ledge, attesting its greater extension in past times. The outer land-rings of both these atolls are covered with vegetation. We could see in the lagoons several rocky islets, the remnants of the elevated limestone ledge.

Matahiva is interesting, as its lagoon is quite shallow; it is full of rocky islets, remnants of the underlying coralliferous limestone ledge which crops

out above the general level, and has a very narrow and shallow entrance, passable for boats only. Some of its islands are wooded and appear to have been formed by accretion of sand from the decomposing ledges of the lagoon. The outer land-rim appears as if formed by sand-banks driven in from the sea face and also driven out from the lagoon side by the action of the waves. It is evident that a lagoon such as Matahiva could readily be closed by such a process and the sea no longer have access to it, as it now has only one very narrow and very shallow boat-passage connecting the lagoon with the sea on the lee side.

It was with great interest that we approached Makatea, as it is the only high elevated island of which Dana speaks as occurring in the western Paumotus.[1] For though he mentions some others as possibly having been elevated five to six feet, yet he considered them all, as well as Makatea (Metia, or Aurora, of Dana) as modern elevated reefs. From the very description given by him of the character of the cliffs and of the surface of Makatea, I felt satisfied that it was composed of the same elevated coralliferous limestone so characteristic of the elevated reefs of Fiji, and which from the evidence of the fossils and the character of the rock, both Mr. Dall and myself have been led to regard as of Tertiary age.

As we approached the island from the northwest it soon became evident that it presented all the characteristics to which I had become so accustomed in Fiji, and, upon landing, this was found to be the case. The cliffs had the same appearance as those of Vatu Leile, Ongea, Mango, Kambara, Yangasá, and many other elevated islands of Fiji. There were fewer fossils, perhaps, but otherwise the petrographic character of the rock was identical with that of Fiji. Mr. Mayer collected upon the top of the second terrace a number of fossils similar in all respects to those we found in the Fiji elevated coralliferous limestones.

The southwestern extremity of the island slopes gradually to the sea and shows two well-defined terraces. The lines of these two terraces could, as a rule, be traced along the faces of the vertical cliffs by the presence of caverns along the lines of those levels, similar to the lines of

[1] Corals and Coral Islands, 3d ed., 1890, p. 193.

caverns indicating the line of present action of the sea at the base of the cliffs. As we steamed around the island there were distinct indications of two additional terraces on the line of the vertical cliffs on the weather side of the island. The position of these terraces was usually more clearly seen along the face of the cliffs at prominent points, where they were undercut much as I have figured them for certain cliffs in Vatu Leile, Yangasá, Mango, Fulanga, and others in Fiji, in my report on the islands and coral reefs of that group.[1]

Of course it is premature, from this examination of the western extremity of the Paumotus, to base any general conclusions regarding the mode of formation of those atolls; certainly, as far as I have gone, there is absolutely nothing to show that the atolls of the Paumotus have not been formed in an area of elevation similar to that of Fiji. The evidence in Rangiroa and in the atolls of the western Paumotus is very definite. Makatea is an elevated mass of coralliferous limestone similar in all respects to masses like Vatu Vara, Thithia, and others in Fiji. Like them, Makatea is surrounded by a comparatively narrow shore platform cut out from the base of the limestone cliffs, and on the seaward extension of which corals grow abundantly to depths of seven to eight fathoms, when they appear to become very much less numerous. So that it is not unnatural to look upon the area of the Paumotus, as I am inclined to do, as one of elevation, the raised and elevated land of which has been affected much in the same way, by denudation and by erosion, as have the masses of elevated coralliferous limestone of Fiji. Only there seems to have been, from the evidence thus far presented, a far greater uniformity in the height of the elevation of the Paumotus. This would render the explanation I have given less evident had I not the experience of the Fiji group to guide me. Evidence of this elevation is found at the two extremities of the Paumotu Plateau, at Makatea, an elevated island consisting of Tertiary coralliferous limestone, and at the Gambier Islands, which are volcanic islands of considerable height (over 1300 feet). Furthermore, as we shall see, there are other islands and atolls in the Paumotu Group showing traces of this elevation, so that I am at any rate

[1] Bull. M. C. Z., Vol. XXXIII., 1899, Pls. 80, 84, 92, 100.

justified in denying that the Paumotus as such are situated in an area of subsidence, and that subsidence has been the great factor, as is maintained by Darwin and Dana, in the formation of the characteristic atolls of the group.

It may be well to point out also that the Paumotus, like the Marquesas on one side and the Society Islands on the other, are situated upon a plateau similar to that upon which the last-mentioned groups are placed, a plateau rising from an oceanic basin which surrounds them, and which has a depth of from 2300 to 2500 fathoms, the plateau itself having a depth of 1200 to 1500 fathoms. For the differences which distinguish the plateaux of these groups I refer to the accompanying charts.

During our stay in Papeete[1] some time was spent in examining that part of the barrier reef of Tahiti which had been surveyed by the "Challenger." We found the condition of the outer slope of the reef quite different from its description as given in the "Challenger" narrative.[2] The growing corals were comparatively few in number, and the outer slope showed nothing but a mass of dead corals and dead coral bowlders beyond sixteen or seventeen fathoms, few living corals being observed beyond ten to twelve fathoms.

We also made an expedition to Point Venus, to determine, if possible, the rate of growth of the corals on Dolphin Bank from the marks which had been placed on Point Venus by Wilkes, in 1839,[3] and by MM. Le Clerc and de Bénazé, of the French navy, in 1869. We found the stones and marks as described, but in view of the nature and condition of Dolphin Bank, did not think it worth while to make a careful survey, as Captain Moser had intended to do. On examining Dolphin Bank in the steam launch I was greatly surprised to find that there were but few corals growing on it. I could see nothing but sparsely scattered heads, none

[1] Explorations of the "Albatross" in the Pacific. II. The Paumotus. [Letter No. 2, dated Papeete Harbor, Tahiti Island, November 6, 1899, to Hon. George M. Bowers, U. S. Commissioner of Fish and Fisheries, Washington, D. C., by Alexander Agassiz.] Am. Jour. Sci., Fourth Series, Vol. IX., No. 50, February, 1900.

[2] Voyage of the "Challenger," Narrative of the Cruise, 2d Part of Vol. I., p. 778.

[3] U. S. Exploring Expedition Narrative, Vol. II.

larger than my fist! — the top of the bank being entirely covered by nullipores. We sounded across the bank in all possible directions, and examined it thoroughly with the water-glass, and at the stage of water at which we sounded found about eighteen inches difference from the soundings indicated by the charts. It is also greatly to be regretted that Dolphin Bank was not examined, either in 1839 or in 1869, and notes made of what species of corals, if any, were growing on its surface; for an excellent opportunity has been lost to determine the growth of corals during a period of sixty years. The choice of this bank as a standard to determine the growth of corals was unfortunate, as it is in the midst of an area comparatively free from corals.

After refitting and coaling here, we left on the 5th October for a cruise in the Paumotus.

We steamed for Makatea, which we had visited on our way to Tahiti, and not only examined the island more in detail, but took a number of photographs of the cliffs of the east side, which, on our first trip, we passed late in the afternoon. We crossed the island from west to east, the path leading down from the summit of the cliffs bordering the island into a sink at least forty to fifty feet lower than the rim of either face of the island. The sink occupies a little more than one-third the length of the island. It is deeper at its southern extremity, where it is said to be seventy-five to one hundred feet below the rim of the adjoining cliffs.

It is difficult to determine if this sink is the remnant of the former lagoon of the island, or of a sound formed during its elevation; or if it has been formed by the action of rain and atmospheric agencies. The amount of denudation and erosion to which this island has been subjected is very great, as is clearly indicated by the small cañons, pinnacles, and walls of limestone, as well as by the crevasses which occur in the surface of the basin in all directions. The extent to which this action has penetrated into the mass of the island is also plainly shown by the great number of caverns which crop out at all levels along the sea face of the cliffs, some of which are of great height and extend as long galleries into the interior of the island. It is, of course, difficult, in the

face of this extensive denudation and erosion, to state positively what may be part of the ancient lagoon, or sound, and what has been carried away by atmospheric and other agencies since the elevation of the island. At the south end of the island, which is lower than the northern part, there are only two distinct terraces, while at the northern end four terraces can be traced. The southern extremity, however, is still higher than the deepest part of the central sink of the island.

From Makatea, we visited Niau, Apataki, Tikei, Fakarava, Anaa, Tahanea, Raroia, Takume, Taenga, Makemo, Tekokoto, Hikueru, Marokau, Hao, Aki-Aki, Nukutavake, going as far east as Pinaki, when we turned westward again, to Nukutipipi.

On arriving at Pinaki we decided to give up the exploration of the eastern extremity of the Paumotus, and not to make our contemplated visit to the Gambier Islands, our time having been greatly curtailed by delays at Fakarava and Makemo, from bad weather and the non-arrival of our coal supply. We therefore reluctantly turned westward again and made for the Gloucester Islands. These, as well as Hereheretue, proved most interesting; they formed, as it were, an epitome of what we had seen on a gigantic scale in the larger atolls of the western and central Paumotus. We could see at a glance in such small atolls as Nukutipipi and Anu-Anurunga the connection between structural features which, in an atoll of forty miles in length and from ten to fifteen miles in width, it was often difficult to determine.

We anchored in Fakarava and Makemo lagoons, spending a number of days in both these atolls. We usually timed our visits to the islands where we could not anchor so as to spend the day, or the greater part of the day, at these atolls, making our passages at night, and sounding whenever practicable on the way.

After leaving Tahiti we made over 100 soundings. These have shown in a general way that the western islands are probably all on a great plateau connected perhaps by the 800-fathom line; that such islands as Anaa are probably on spurs or independent smaller plateaux, separated from the main plateau by somewhat deeper water; the same may be the condition of Raroia and Takume, and of Hao and Amanu, while such

smaller and isolated islands as Tikei, Aki-Aki, Nukutavake, and Pinaki, as well as the Gloucester Islands, rise from greater depths and are isolated peaks. At any rate, these soundings indicate, as do the soundings off the Fijis, that atolls do not necessarily rise from very great depths, and that in this characteristic atoll district, atolls are found, it is true, with steep slopes, but rising from moderate depths. The slopes of these atolls would probably resemble in every respect the slopes of the elevated coralliferous limestone islands characteristic of the Lau Group in Fiji, where they have not been obliterated by erosion, denudation, and atmospheric agencies.

The deepest sounding among the Paumotus was on the line to the northward of Hereheretue in the direction of Mehetia, where we found a depth of 2524 fathoms, and a continuation of the red clay characterizing the soundings since we left Pinaki. In nearly all the soundings among the Paumotus, even at moderate depths not far from the atolls, we brought up manganese particles or small manganese nodules. The last haul, made in deep water on the way from Hereheretue, in 2440 fathoms, on the way to Mehetia, brought at least half a ton of manganese nodules, the bottom being red clay.

We steamed about 2500 miles among the Paumotus, and although we had not the advantage of the accurate surveys of the English Hydrographic charts, which made the exploration of Fiji so easy, yet from the structure of these atolls it was a comparatively simple task, by steaming around the islands and landing wherever practicable, to get a fairly good idea of their structure. We have seen nothing in this more extended examination of the group tending to show that there has anywhere been subsidence. On the contrary, the existing condition of the atolls of the Paumotus cannot, it seems to me, be explained on any other theory except that they have been formed in an area of elevation; an area of elevation extending from Matahiva on the west to Pinaki in the east, and from the Gloucester Islands on the south to Tikei on the north, although the islands in the line of Mangareva to Tahiti are separated from the other Paumotus by a deep channel, nearly 200 miles wide and more than 2400 fathoms in depth, with scattered islets and atolls extending from Mangareva to Pinaki, and northward to Puka-ruha

and beyond, islands which are not connected with the extensive plateau upon which the greater number of the Paumotu Islands to the westward of Hao rise.

All the islands we have examined are, without exception, formed of Tertiary coralliferous limestone, which has been elevated to a greater or less extent above the level of the sea, and then planed down by atmospheric agencies and submarine erosion, the greatest elevation being at Makatea (about 230 feet), and at Niau, where the Tertiary coralliferous limestone does not rise to a greater height than twenty feet. At Rangiroa it was fifteen to sixteen feet high. At other islands it could be traced only as forming the shore platform, from fifty to 250 feet wide, which forms the outer face of the Paumotus and is so characteristic a feature of the atolls of the group. In other parts the old ledge could be traced cropping up in the interior of the outer land-rim, or in the open cuts connecting the lagoon with the outer sea-face of the atolls. Everywhere the space between the outcroppings of the old ledge, as I will call the Tertiary coralliferous limestone, was filled with beach rock, or a pudding-stone, or with a breccia or conglomerate of coralliferous material consisting in part of fragments of the old ledge, and of fragments of recent corals and shells cemented together.

The appearance of the old ledge and of the modern reef-rock is so strikingly different that it is very simple to distinguish the two, even where only comparatively small fragments are found.

We did not find in the Paumotus, as in Fiji, all possible stages of denudation and of submarine erosion between islands like Vatu Vara, Naiau, Kambara, Fulanga, Ongea, Oneata, Ngele Levu, and Wailangilala, and atolls with a mere ring of surf to indicate their existence.

In the Paumotus nearly all the islands have been elevated to a very moderate height and probably to about the same height, for the old ledge forming the base of the modern structure is found exposed nearly everywhere at about low-water when it cannot be traced at a slightly greater elevation. This would readily account for the uniform height of the islands throughout the group.

But there is another element which comes into play in this group, and has an important part in shaping the ultimate condition of these atolls. At

the Fijis we have seen the submarine erosion continue until there is little left of many of the atolls beyond the merest islet or rock to indicate its structure. In the Paumotus, in the great atolls, which are perhaps only the exposed summits of parts of ridges or spurs of an extensive Tertiary coralliferous limestone bed, the land-rim of the atoll is, after having been denuded to the level of the sea, again built up from the material of its two faces, which is thrown up on the wide reef-flats both from the sea face and from the lagoon side. We do not find in the Fijis, as in the Paumotus, the wide reef-shelves which supply such masses of material from the breaking up of the outer and inner edges of the Tertiary limestone platforms, in addition to the fragments of the recent corals growing upon the flats and their slopes, which, when dead, are thrown up on the top of the reef flats and formed into shingle and sand to form a pudding-stone, or a conglomerate, or breccia, with the fragments of the old ledge.

This pudding-stone, or beach rock, is found on all the reef flats of the islands of the group. It forms great bars, at right angles usually to the shore-line, and upon the sea face of these bars is thrown up coral shingle, both old and recent, which builds up short reaches of beaches separated by wide flats through which the sea rushes at high-water, or merely covers the flats at low tide; while on the lagoon side of the wide reef-flats a similar process is going on, throwing up finer sand among the beach-rock bars and along their sides, and thus building up little by little, at first small sand-bars, then larger bars, or islets, at right angles to the shore-line, and as they become larger by accretions from both sides, they finally form islands from 1000 to 1200 feet long, according to the width of the reef flat, extending from the lagoon edge of the flat to the sea face of the atoll. The sand-bars, little by little, become covered with vegetation, and at some stages of tide appear like islands and islets situated a considerable distance within the lagoon. Whenever the material supplied both from the lagoon side and from the sea face is very abundant, the land ring becomes more or less solid, the islets become consolidated into islands, separated by narrow or wider cuts, until finally they form the larger islands which seem at first glance to form a continuous land-rim along the edge of the lagoon, but which are often seen to be separated according to local conditions by narrow

cuts, which gradually silting up finally allow no water to pass through and merely indicate the former separation of the various parts of the land.

In the lagoons of atolls of such great length as some of those of the Paumotus, like Rangiroa, Fakarava, Makemo, and Hao, which are between thirty and forty miles long, and others of less dimensions, considerable sea rises under the prevailing trades. The sea and wind generally follow the trend of the shores, both in the lagoon and along the sea face, so that the bars of beach-rock act like buttresses and collect material at their inner and outer extremities, forming the sand-bars and islets which eventually become the land-rim of the lagoon. When the material is not, from local causes, very abundant, or is washed out over the flats, there are fewer islands, and often these are but mere islets or bars for long reaches of the submerged land-rim, forming the characteristic weather-faces of many of the lagoons.

Many of the lagoons are filled with shoals or ledges awash or a few feet above the sea level. These shoals are parts of the old ledge which have not as yet been eroded, and the disintegration of which has gone far to supply the material for the land of the outer rims of the atolls. In Fakarava there were no less than thirty-six islands and islets and ledges, parts of a former great flat, now broken up, existing parallel to the outer reef-flat about four miles in the lagoon. Similar reef flats exist in Tahanea, where they form a secondary lagoon with two to three fathoms of water, extending nearly the whole length of the western face of the atoll. There are several large islands on this flat, and at high water they would appear, as the islands and islets of Fakarava do, as disconnected and planted in the lagoon itself. A secondary lagoon also exists in Ravahere, and in Anaa; in both these atolls the reef flat extends across one extremity of the lagoon, and does not run parallel to the longer line of the land-rim of the atoll.

The lagoons of these atolls have a general depth of thirteen to twenty fathoms. In some cases they are somewhat deeper, as is stated, but there are no measurements, the greater depths, thirty fathoms or more, being due probably to orogenic conditions. Some of the atolls are quite shallow, as at Matahiva, as well as Pinaki, where the lagoon is not more than two to three fathoms, and Takume, where it is from five to six fathoms

deep. Some of the smaller islets we visited, among which are Tikei, Aki-Aki, and Nukutavake, have no lagoons. The former has a small shallow sink in which fresh water collects, but the rim is only very slightly higher than the interior. The last two islets are apparently depressed in the centre, three to four feet below the outer bank of sand which forms the rim (about ten to twelve feet high) of the basin of the island. I was at first inclined to look upon these islands as examples of islands which had been cut down to the level of the sea and subsequently been built up by beach rock and sand in the manner described above. The existence of extensive sand dunes on two sides of the island at Pinaki, and of large dunes (estimated to be thirty-five feet high) on the south shore of Nukutavake, seems to indicate the possibility of there having been a shallow lagoon occupying the centre of Aki-Aki and of Nukutavake, and that these lagoons were gradually filled by the sand dunes, much as Pinaki is filling now.

At Pinaki (Whitsunday Island), there is no doubt that the lagoon is rapidly filling from the sand blown in by the dunes. They are from twelve to fifteen feet high, and are forcing their way in towards the lagoon, killing the pandanus and whatever vegetation there is growing on the land-rim of the lagoon. The dunes have probably filled also a second entrance to the lagoon, indicated now only by a somewhat lower level of the land-rim. Dr. Moore and Mr. Townsend, who went ashore at Pinaki, report that the lagoon is not more than three fathoms deep; they could wade over the greater part of it. Mr. Alexander counted no less than 116 islets in this small lagoon—less than a mile in diameter—islets formed of masses of dead Tridacna shells thrown up on ledge rock, on the slopes of which grew madrepores. The bottom of the lagoon is covered by Tridacna, and masses of a species of Arca live near the edge; the intervening spaces being filled with nullipores. The entrance to the lagoon is perhaps 150 feet wide, and there is a cut through the beach rock covering the old ledge giving access to the sea into the lagoon at certain stages of the tide. The water in the lagoon is quite warm.

At Pinaki, as at other atolls and islets to the eastward, there are fewer cocoanuts than on the westward atolls, and the vegetation consists

in great part of pandanus and putu trees and the usual coral-reef vegetation of the Paumotus[1] and Fijis.

The only atoll we have seen in the Paumotus the lagoon of which is entirely shut off from the sea is Niau. In this case the old ledge forming the land-rim which surrounds the nearly circular lagoon is about a third of a mile in width and sufficiently high, fifteen to twenty feet, to prevent any sea from having access to it except in case of a cyclone, as that of 1878, when the sea washed into the lagoon. The lagoon is shallow, of an average depth of about three fathoms, the deeper parts perhaps five. The water is brackish, of a density of 1.0216 at 28° C. There are no corals living in it, but a species of mullet is found, as well as many marine shells, which, like those in the lagoons of San Salvador, in the Bahamas, are of diminutive size compared to their representatives living outside. The floor of the lagoon is covered with algæ. The lagoon has probably a slight connection with the sea, the water percolating through the limestone ring separating it from the outer reef-flat. It is very difficult in this case to decide whether this lagoon has been gradually filled up after elevation, or whether it is merely a sink formed by solution and atmospheric erosion on a more or less uneven limestone surface.

Dana, and other writers on coral reefs, mention a great number of lagoons as being absolutely shut off from the sea. I take it these statements are due to their descriptions being taken from charts, many of which, as in the case of the Paumotus, are very defective. For nothing is easier than to pass at a short distance by the wide and narrow cuts which give in so many cases the freest access to the sea to the interior of the lagoon, and are described as closed because they have no boat passages. I could mention, as instances of such lagoons, those of the atolls of Takume, Hikueru, Anaa, etc., which may be said to be closed, yet into which a huge volume of water is poured at every tide over low parts of the encircling reef-flats.

The character of the coral reefs of the Paumotus is very different from that of other coral-reef regions I have seen. Nowhere have I seen

[1] See Dana, Corals and Coral Islands, 3d ed. p. 326.

such a small number of genera, so many small species, and such stunted development of the corals. None of the great heads of the genera so characteristic of the West Indian regions, or of the Great Barrier Reef of Australia, are to be seen; with the exception of a couple of species, alcyonaria are absent, so far as our experience shows, and there are but few sponges and gorgonians to be found among the corals. The bathymetrical limit of the reef-building corals seems to be about twenty to twenty-two fathoms, but nowhere have I seen such extraordinary development of incrusting nullipores as on the sea edge of the shore platforms of some of the Paumotu atolls, where they build up to a height often of four feet to form the outer edge of the secondary barrier reef so frequently seen along the sea reef-faces of the Paumotus.

Judging from the temperatures taken at various points, 40° F. seems to be found quite generally at about 500 fathoms depth.

We made a number of surface hauls, as well as intermediate hauls with the tow-nets, but obtained very little animal life in the Paumotus. The poverty of the surface pelagic life and down to 300 fathoms is remarkable. I do not think I have ever sailed over so extensive an area as that of the Paumotus and observed so little surface life; on calm days, under the most favorable conditions, nothing could be seen with the naked eye, and at night there was little or no phosphorescence. Inside of the lagoons our hauls were equally barren.

The same paucity of animal life seemed to extend to the deep-water fauna. All the hauls we made off the islands, in from 600 to 1000 fathoms, usually the most productive area of a sea slope, brought nothing, or so little that we came to grudge the time spent in trawling on the bottom, as well as towing on the surface or near it,—a great contrast to the conditions in the Atlantic in similar latitudes, and very different from our anticipations.

For these reasons we did not attempt to make a trial of the deep-sea pump while in such unproductive areas; and unfortunately while we were in the region of the equatorial currents the weather conditions were not suited for a trial of the apparatus.

We left Papeete,[1] November 15th, after coaling and refitting on our return from the Paumotus. During our trip to Suva we made a few soundings from Tahiti to Tonga, striking the northern extension of the deep basin lying to the eastward of Niue; the depths ranged from 2472 to 2882, the bottom being red clay. This would indicate a greater extension westward of the zone over which the manganese-nodule bottom is known to extend.

After leaving Niue we steamed for the deep hole of the Tonga-Kermadec Deep, about seventy-five miles to the eastward of Tongatábu, and in 4173 fathoms made a haul with the "Blake" beam-trawl, by far the deepest trawl-haul yet made. The gear was carefully inspected, and strengthened as far as practicable by Captain Moser, and it was with considerable anxiety that we laid out 5000 fathoms of wire rope for our haul. Fortunately, everything went off successfully, and we landed the trawl safely back on deck. To my great surprise we found in the bag a number of large fragments of a silicious sponge belonging probably to the genus Crateromorpha, which had been obtained by the "Challenger" in the Western Pacific, but in depths less than 500 fathoms. We also brought up quite a large sample of the bottom; it consisted of light-brown volcanic mud mixed with Radiolarians.

We decided to trawl at 4173 fathoms rather than wait for a possibly deeper sounding, as the conditions for work were admirable and we did not care to run any risk from a change of weather. After our haul we made a still deeper sounding in the proximity of the 4762-fathom sounding marked on the chart, and found 4540 fathoms, with the bottom of the same character as at the place where we trawled. We also took a couple of soundings in the line from Vavau to the southern extremity of the Lau Group in Fiji, but found, as we expected from the soundings given farther south, comparatively shoal water, viz.: 1381 fathoms. In the channel north of Yangasá, where we crossed the Lau Plateau, between Yangasá and Mothe, we found 453 fathoms, with bottom composed of coral sand,

[1] Explorations of the "Albatross" in the Pacific. III. [Letter No. 3, dated Suva Harbor, Fiji Islands, December 11th, 1899, to Hon. George M. Bowers, U. S. Commissioner of Fish and Fisheries, Washington, D. C., by Alexander Agassiz.] Am. Jour. Sci., Fourth Series, Vol. IX., No. 51, March, 1900.

pteropod ooze, and a few Globigerinæ. Between Namuka and Yangasá we obtained 324 fathoms; between Namuka and Marambo, 600 fathoms; between it and Kambara, 450 fathoms; and finally, about fifteen miles west of Kambara, we sounded in 990 fathoms. These soundings would indicate a continuous plateau of moderate depths from Wailangilala south, upon which the islands of the Lau Group rise.

On our way back to Papeete from the Paumotus we examined the eastern cost of Tahiti, and from Papeete examined the western coast as far as Port Phaeton, at Taravoa Isthmus. We examined, in a general way, the Leeward Society Islands: Murea, Huaheine, Raiatea, Tahaa, Bora-Bora, Motu Iti, and Maupiti. There are excellent charts of the Society Islands, so that it was comparatively simple to examine the typical points of the group and to gain an idea of their structure as far as it relates to coral reefs. The Society Islands are all volcanic islands edged with shore platforms, some of great width, upon which the barrier or the fringing reefs of the islands have grown. The structure of the reefs of the Society Islands is very similar to that of the Fiji reefs round volcanic islands. A comparison, for instance, of the charts of Kandavu, Viti Levu, Mbengha, Nairai, and of other volcanic islands in the Fijis, with those of the Society Group, will at once show the identity of their structure. Huge platforms of submarine denudation and erosion characterize both, with fringing and barrier reefs determined by local conditions. Perhaps it is easier to follow the changes which have taken place in the Society Islands; and such islands as Tahaa and Bora-Bora, where we anchored, as well as Maupiti, are admirable examples and epitomes of the structure and mode of formation of the coral reefs of that group.

In Motu Iti and Tetiaroa the volcanic peaks have disappeared, leaving nothing but a shallow platform, upon the outer edges of which sandy coral islets have been thrown up. There is, however, one point in which the barrier reefs of the Society Islands differ from those of Fiji. The barrier reefs in Fiji are generally indicated merely by reef flats, upon which the sea breaks, and an occasional rocky islet or negro-head; only rarely do we find sand keys upon the fringing reefs of the islands of Fiji. In the Society Islands, on the contrary, we find the line of the barrier reefs usually well

indicated by long lines of narrow islets thrown up on the reef platforms, exactly as they are in the Paumotus. These islands and islets are usually well wooded, and thus give a very peculiar aspect to the barrier reef. In the case of Bora-Bora, Maupiti, and Aitutaki, for instance, we have a central volcanic peak of considerable height surrounded by a wide lagoon, the sea edge of which is formed by a fringe of wooded islets and islands forming a more than half-closed ring around the central island, which, in Bora-Bora and Maupiti, rise in slopes and nearly vertical walls, the former to a height of nearly 2400 feet, the other to about 800 feet.

The only island of the Cook Group which we examined was Aitutaki; as Atiu is composed of elevated limestone, and Rarotonga is volcanic, I hoped we might find that atoll to be in part volcanic and in part composed of elevated coralliferous limestone; we found it to be volcanic, an island with the structure of Bora-Bora on a smaller scale.

We anchored at Niue, an island composed of elevated coralliferous limestone showing three well-marked terraces, the lowest of not more than five to ten feet, and in many places disappearing completely, the limestone cliffs rising vertically from the sea well into the second or even the third terraces. The vertical faces of the cliffs are dotted with caverns and deeply indented by small cañons extending at right angles to the face of the shore or forming blunt headlands separating short reaches of coral-sand beaches.

The second terrace varies in height from fifty to sixty feet, the third from ninety to 100 feet. The second terrace is deeply undercut, and in the higher vertical cliffs extending into the third terrace from the sea, the former positions of the terraces are usually indicated by lines of caverns. There are corals on the sea slopes of the first terrace, extending down to ten or twelve fathoms, growing much as they are found at Makatea.

From Niue we went to the Tongas, which we found a most interesting group. The elevated Tertiary coralliferous limestones take here their greatest development, and are on a scale far beyond that of their development in the Lau Group of the Fijis, or the Paumotus. The first island of the Tongas we visited, Eua, is perhaps the most interesting of the islands composed of Tertiary elevated coralliferous limestone I have visited. From Dana's

account of it,[1] evidently given at second-hand, I expected to find an island somewhat like Viti Levu on a very much smaller scale. But as we steamed up to it from the east there could be no mistaking the magnificent face of nearly vertical limestone cliffs forming the whole eastern face of the island, and at points rising to over a thousand feet in height. At all projecting points lines of terraces were plainly marked: at the northern point three could be followed, and at the southern extremity five, with traces of a sixth perhaps.

Upon rounding the southern extremity of the island we could see that the island was composed of two ridges, running north, separated by a deep valley, the western ridge being much lower than the eastern,[2] only rising to a height a little over 500 feet. The western ridge is also composed of limestone, and at the headlands we could trace three terraces. There is a narrow shore platform along the western face, at many points of which there are blow-holes where the sea throws up spray to a considerable height, but these blow-holes are best seen off Cook Point, the southern extremity of Tongatábu.

As we steamed along the western face of Eua Island we could see the higher ridges of the eastern side rising above the lower crest of the western ridge, the slopes indicating a valley of considerable size running between them. We anchored at English Roads opposite the outlet of the drainage of the interior basin, where a small river has cut its way through a depression in the shore terrace. On landing we followed the crest of the western ridge for a few miles and could see the whole valley forming the basin of the island lying between the two ridges, at our feet; the slopes leading to the bottom are quite gentle, and the valley dips very gradually northward back of the outlet on the western shore. Nothing could show more clearly that such an island was not an elevated atoll, but a plateau which has been eroded and denuded for a long period of time by atmospheric and other agencies, and in which a deep basin-shaped valley with gentle slopes has been gouged out, — a plateau originally similar to that of Tongatábu Island and of Vavau, but of greater height and less extent.

[1] Corals and Coral Islands, 3d ed., p. 373.

[2] The western slope of the eastern ridge is partly volcanic.

To the westward of the Tonga Islands a line of volcanic islands extends nearly 200 miles, from Honga Hapai to Fanua lai, some of which have been active very recently. Falcon Island disappeared in 1898, and Letté is still active. This line of volcanoes runs at a distance of from fifteen to twenty miles parallel with the trend of the four irregularly shaped plateaux upon which rise the Tonga Islands. They are the summits of a great ridge, over 200 miles in length, sloping very gradually to the westward into deep water, and being somewhat steeper to the eastward, towards the smaller platforms from which rise the volcanic peaks of the group. The plateaux of Tongatábu, Nomuka, Haapai, and Vavau, are separated by deep valleys connecting the eastern and western flanks of the ridge. These four plateaux rise abruptly from the 100-fathom line. The extremity of the southern one is occupied by Tongatábu Island. The land behind the cliffs of its southern coast rises to a height of over 250 feet, and slopes northward very gradually to form the low land which occupies the northern coast of the island, and is, except at Mount Zion and Cook Hill, not more than from five to twenty feet above the level of the sea. At Cook Point and along the southern coast three terraces are indicated. The northern coast is deeply indented by shallow bays, full of islands, reef flats, and reef patches, on which corals grow in great profusion. For a distance of nearly ten miles northward of Nukualofa the plateau is nowhere more than fifteen fathoms deep; and a long tongue runs northward, gradually deepening into twenty to fifty fathoms to the 100-fathom line.

The Tongatábu plateau is separated from the Nomuka Group plateau by a funnel-shaped channel with a depth passing rapidly into 300 fathoms from the 100-fathom line. The Nomuka plateau is rectangular. The principal island is Nomuka, where we anchored. We found the island to be composed of Tertiary elevated coralliferous limestone, with a shallow sink, filled with brackish water, occupying the southeastern part of the island. The sink is separated by a high sand-beach, about 200 yards wide, from the sea.

Nomuka Iki, the island next to Nomuka, we found to consist, at its southern extremity, of stratified volcanic material, resembling somewhat

the so-called soapstone of Fiji. I was informed that other islands in this group, near Tonumeia, in the centre of the Nomuka plateau, were volcanic. Mango, as we could see it from our anchorage, appeared to be volcanic. So that this part of the Tongas is, like the Lau Group in Fiji, made up of islands in part volcanic and in part composed of elevated coralliferous limestone. The eastern edge of the Nomuka plateau (which we did not visit) is edged with small low islands. We merely steamed by the western islands of the Haapai Group, but close enough to see that Tongua, Kotu, and Fotuhaa, which vary in height from 120 to 200 feet, are composed of elevated limestone. The eastern flank of the Haapai plateau is edged with long, low islands, with extensive coral reefs along the reef flats of these islands.

The Haapai plateau is triangular, with isolated islands rising on the northwestern side from the deep water separating it from the Vavau plateau. It is separated from the Nomuka plateau by a narrow channel with over 300 fathoms of water.

The northernmost plateau of the broad ridge of the Tonga Islands is the Vavau plateau. This is elliptical, with a long tongue extending on the eastern face of the ridge toward the northern point of the Haapai plateau, ending in isolated banks (the Disney reef and Falcon bank), lying to the northward of the broad channel, with over 400 fathoms separating it from the Haapai Group. The Vavau Group is by far the most picturesque of the Tonga Islands. It consists of the principal island of Vavau, extending across the northern part of the Vavau plateau. Several parts of the island of Vavau, as at the southwestern extremity, at the entrance to the harbor of Neiafu, and at Neiafu, are finely terraced; four terraces are indicated there, and other flat-topped smaller islands show traces of two or three terraces. The northern edge of Vavau Island rises to a height of more than 500 feet, and slopes in a general way southward and inland. The southern shore is deeply indented by bays and sounds, and flanked by innumerable islands and islets, some of considerable height (150 to 250 feet) which gradually become smaller and smaller as they rise toward the southward and eastward, these islands having been formed from the denudation and erosion

of the greater Vavau. They form tongues of land and sea and sounds of all shapes and sizes, showing the traces of the former land connections of the islands and islets, and their disintegration on the eastward and southward by the action of the sea. The islands and islets to the southward of the main island rise from more or less extensive reef flats which stud the whole plateau, and on which corals grow in great profusion (mainly Millepora, Porites, Pavonia, Pocillopora, Fungia, and Astrea), to a depth of five to six fathoms in the sounds. In the Nomuka Group they extended in the more open waters to fourteen and sixteen fathoms.

It is evident that in the Tonga Group, which is a very extensive area of elevation, the recent corals have played no part in the formation of the masses of land and of the plateau of the Tonga Ridge, and that here again, as in the Society Islands and the Cook Islands, both also in areas of elevation, they are a mere thin living shell or crust growing at their characteristic depths upon platforms which in the one case are volcanic, in the other calcareous, the formation of which has been independent of their growth.

After coaling and refitting we left Suva[1] on the 19th of December, and arrived at Funafuti on the 23d, stopping on the way at Nurakita, the southernmost of the Ellice Islands. I was, of course, greatly interested in my visit at Funafuti, where a boring had been made under the direction of a committee of the Royal Society, in charge of Professor David, of Sydney, after the first attempt under Professor Sollas had failed. The second boring reached a depth of more than 1100 feet. This is not the place to discuss the bearing of the work done at Funafuti, as beyond the fact of the depth reached we have as yet no final statement by the committee of the interpretation put upon the detailed examination of the core obtained, and now in the hands of Professor Judd and his assistants. In addition to the above-named islands, we also examined Nukufetau, another of the Ellice Group.

[1] Explorations of the "Albatross" in the Pacific. IV. [Letter No. 4, on the Cruise of the "Albatross," dated Yokohama, Japan, March 5, 1900, to Hon. George M. Bowers, U. S. Commissioner of Fish and Fisheries, Washington, D. C., by Alexander Agassiz.] Am. Jour. Sci., Fourth Series, Vol. IX., No. 53, May, 1900.

After leaving Nukufetau we encountered nothing but bad weather, which put a stop to all our work until we arrived under the lee of Arorai, the southernmost of the Gilbert Islands. On our way from Taputeuea we steamed to Apamama and Maiana, which we examined, as well as Tarawa. We next examined Maraki, an atoll which is nearly closed with high beaches, having only two small boat passages leading through the narrow outer land-rims. Both Maraki and Taritari, the last island of the Gilberts which we visited, are remarkable for the development of an inner row of islands and sand-bars in certain parts of the lagoon parallel to the outer land-rim, a feature which also exists in many of the Marshall Islands atolls.

We reached Jaluit the 9th of January, and after a few days spent in coaling, we passed about three weeks in exploring the Marshall Islands, taking in turn the atolls of the Ralick Chain to the north of Jaluit: Ailinglab Lab, Namu, Kwajalong, and Rongelab, and then some of the atolls of the Ratack Chain, Likieb, Wotje, and Arhno. The atolls of the Marshall Group are noted for their great size and the comparatively small area of the outer land-rims, the land-rims of some of the atolls being reduced to a few insignificant islands and islets. In none of the atolls of the Ellice, Gilbert, or Marshall Islands were we able to observe the character of the underlying base which forms the foundations of the land areas of these groups. In this respect these groups are in striking contrast to the Paumotus, the Society Islands, the Cook Group, Niue, the Tongas, and the Fiji Islands, where the character of the underlying foundations of the land-rims is readily ascertained. But, on the other hand, these groups give us the means of studying the mode of formation of the land-rims in a most satisfactory manner, and nowhere have we been able to study as clearly the results of the various agencies at work in shaping the endless variations produced in the islands and islets of the land-rims of the different atolls by the incessant handling and rehandling of the material in place, or of the fresh material added from the disintegration of the sea or lagoon faces of the outer land-rim, or of the corals on the outer and inner slopes. It has been very interesting to trace the ever-changing conditions which have resulted in producing so many variations in the

appearance and structure of the islands and islets of the land-rims of the different groups.

The boring at Funafuti will show us the character and age of the rocks underlying the mass of recent material of which the land-rim, not only of that atoll, but probably also that of the other atolls of the group and of neighboring groups, is composed, though of course we can only judge by analogy of the probability of the character of the underlying base from that of the nearest islands of which it has been ascertained. When we come to a group like the Marshalls we have as our guide only the character of the base rock of the islands of the Carolines, which is volcanic, while Nauru[1] and Paanopa Islands, to the west of the Gilberts and to the southwest of the Marshalls, indicate a base of ancient Tertiary limestone.

The vegetation of the atolls of the Ellice, Gilbert, and Marshalls is more luxuriant than that of the Paumotus, probably from the greater rainfall, though the number of species of plants so characteristic of the western atolls is not much greater. It is only in the larger western volcanic islands — the Fiji, Samoan, and Caroline group — that we note the marked increase in the number of species of forest trees allied to those occurring still further west, over those on the eastern groups, like the Cook and Society Islands.

Owing to the continued stormy weather and the probability of not being able to land at Nauru and Paanopa while the unfavorable conditions lasted, we did not attempt to visit them.

After leaving Suva we made a number of soundings from south of Nurakita toward the Marshall Group, which, in addition to those of the "Penguin," clearly show that the Ellice Islands are isolated peaks rising from considerable depths (from 1500 to over 2000 fathoms) and that the same is the case with the Gilbert Islands. We made about thirty soundings between the atolls of the Marshalls, which appear to show that they also rise as independent peaks or ridges, with steep slopes, from 2000 to 2500 fathoms, and that the so-called parallel chains of atolls of the Marshalls, the Ralick and Ratack, are really only the summits of isolated peaks rising but a few feet above the sea-level. The Marshall Islands, as well

[1] Nauru von Dr. Augustin Krämer. Globus, Vol. LXXIV., No. 10, September, 1898.

as the Ellice and Gilbert, seem to be somewhat higher than the Paumotus, but this difference is only apparent, and is due to the difference in the height of the tides, which is very small in the Paumotus, while in the former groups it may be five, and even six feet.

From Jaluit we visited among the Carolines, the islands and atolls of Kusaie, Pingelap, Ponapi, Andema, Losap, Nama, the Royalist Group, Truk, and Namonuito, obtaining thus an excellent idea of the character of the high volcanic islands of the group from our examinations of Kusaie and of Ponapi, while the others represent the conditions of the low atolls, having probably a volcanic basis, but this was not observed at any of those we examined.

The reefs of the volcanic islands of the Carolines are similar in character to those of the Society Islands, though there are some features, such as the great width of the platforms of submarine erosion of Ponapi and of Kusaie, and the development of a border of mangrove islands at the base of the volcanic islands, which are not found in the Society Islands.

The Truk Archipelago was perhaps the most interesting of the island groups of the Carolines, and it is the only group of volcanic islands surrounded by an encircling reef which I have thus far seen in the Pacific which at first glance lends any support to the theory of the formation of such island-groups as Truk by subsidence. This group was not visited by either Darwin or Dana; and I can well imagine that an investigator seeing this group among the first coral reefs would readily describe the islands as the summits, nearly denuded, of a great island which had gradually sunk. But a closer examination will readily show, I think, that this group is not an exception to the general rule thus far obtaining in all the island groups of the Pacific I have visited during this trip; that we must look to submarine erosion and to a multitude of local mechanical causes for our explanation of the formation of atolls and of barrier and encircling reefs, and that, on the contrary, subsidence has played no part in bringing about existing conditions of the atolls of the South and Central Pacific.

Nowhere have we seen better exemplified than at Truk how important a part is played by the existence of a submarine platform in the growth

of coral reefs. The encircling reef protects the many islands of the group against a too rapid erosion, so that they are edged by narrow fringing reefs, and nowhere do we find the wide platform so essential to the formation of barrier reefs. The effect of the northeast trades blowing so constantly in one direction for the greater part of the year is of course very great; the disintegration and erosion of islands within its influence is incessant, and their action undoubtedly one of the essential factors in shaping the atolls of the different groups, not only according to the local position of the individual islands, but also according to the geographical position of the groups. Thus far I do not think any observer has given sufficient weight to the importance of the action of the trades in modifying the islands within the limits of the trades; nor has it been noticed that the coral reefs are all situated practically within the limits of the trades, both north and south of the equator. It is interesting to note that there are no coral reefs in two extensive island groups of the Pacific, the Marquesas and the Galapagos, both within the tropics in the same latitudes where far to the westward the Gilbert and other Line islands, as well as the Ellice and Solomon Islands, are noted for the abundance of corals and the great development of coral reefs. At the Galapagos and Marquesas, corals exist only in patches, forming short stretches of fringing reefs, and it is difficult to account for the absence of coral reefs in these groups except on the supposition that the shores are usually too steep, that no great platforms of submarine erosion flank the islands, and finally that the shore cliffs and slopes are readily disintegrated by the action of the sea and afford no permanent foothold to growing corals.

The soundings made going west from Jaluit to Namonuito indicate that there is no great plateau from which the Carolines rise, but that the various groups are, as is the case with the neighboring groups of the Marshalls and Gilberts, isolated peaks with steep slopes rising from a depth of over 2000 fathoms. The line we ran from the northern end of Namonuito to Guam developed the eastern extension of a deep trough running south of the Ladrones. The existence of this trough had been indicated by a sounding of 4475 fathoms to the southwest of Guam made by the "Challenger." We obtained, about 100 miles southeast of

Guam, a depth of 4813 fathoms, a depth surpassed only, if I am not in error, by three soundings made by the "Penguin" in the deep trough extending from Tonga to the Kermadecs, and by two still deeper made by the U. S. S. "Nero"[1] to the eastward of Guam, probably in continuation of the same "Deep" called the "Caroline Deep" by Professor Supan.[2]

I was very much surprised, in approaching Guam from the eastward, to find that the island was not wholly volcanic, but that the northern half consists of elevated coralliferous limestone. The vertical cliffs bordering the eastern face rise to a height of 100 to 250 or 300 feet at the northern extremity, and resemble in every way those of similar limestone islands, such as Makatea, Niue, Eua, Vavau, and others in the Fijis, which had made their cliffs a familiar feature in our explorations. In fact, outside of Viti Levu and Vanua Levu, this is the largest island known to me where we find a combination of volcanic rocks and of elevated coralliferous limestone. The massif forming the southern half of the island is volcanic, and the highest ridge, rising to about 1000 feet, runs parallel to the west coast, the longest slope being toward the east.

This volcanic mass has burst through the limestone near Agaña, and the outer western extension of the coralliferous limestone exists only in the shape of a few spurs running out from the volcanic mass, the largest of which are those forming the port of San Luis d'Apra. These spurs are separated by lower ridges of volcanic rocks extending to the sea from the main central mass. To the north of Agaña the limestone forms an immense irregular mesa, cut by deep crevasses, full of pot-holes and sinks, rising gradually northward to a height of 350 or 400 feet. Near the northern extremity of the island a volcanic mass, Mt. Santa Rosa, has burst through the limestone and rises about 150 feet above the general level of that part of the island. The shore stratification of the bluffs is much distorted in the vicinity of that volcanic outburst.

The formation of huge masses of limestone in which occur at intervals

[1] The deep soundings of the "Nero" have been marked "Nero Deep" in H. O. Chart No. 529, published June, 1900, but it does not give the deep sounding of the "Challenger" to the westward (4475 fathoms), which was the first indication of the probable existence of a deep trough south of Guam.

[2] Petermann's Mitteil., 1899, Vol. 45, VIII., p. 180.

layers of corals or of reef-building corals must have taken place in areas of subsidence, — the subsidence taking place at a comparatively slow rate while the coralliferous belts were deposited, and at a more rapid rate at a greater depth than that at which corals could grow while the non-coralliferous limestones were laid down. This process has nothing in common with the formation of atolls. But when these coralliferous masses of limestone of great thickness were elevated either suddenly or intermittently to heights of more than 1000 feet, the resulting islands in the former case must have represented either a bed deposited near the surface — if coralliferous — enclosing perhaps a lagoon, or a sound, or a basin of solution and erosion, formed in comparatively modern times, with recent corals forming a capping of moderate thickness. In the second case, during each stage of rest the elevated beds were subject to denudation and erosion by the action of the sea. If each stage was an elevation of more than the depth at which corals can grow, the denudation and erosion may have continued long enough to cut the elevated limestone down to, or nearly down to the terrace which marks the uprising of the mass. Or the denudation and erosion may merely have gone far enough to open the circumscribed area to the action of the sea at some points only, and thus to connect what was the lagoon or basin at the first sea-level with the lagoon or basin or sound of the second stage of rest.

One can readily see how complicated the resultant action may become when we take into account the varying height of the different stages of elevation, the condition of the limestone mass and of the coralliferous limestones after the elevation, and the action of denudation and of erosion upon the elevated mass, as well as the solvent action taking place on the summit and sides, and finally the eroding action of the sea upon the interior basin, should it once break through the outer rim of the elevated basin, when its lowest point has reached the level of the sea. This break would thus form an entrance to the lagoon, much as is formed the entrance to any lagoon or sound. Should this mass be elevated a second, a third, or a fourth time, we may find one, or two, or more entrances to the old lagoons and sounds according to the rate of denudation and of erosion of the elevated mass during the periods of rest.

The coralliferous limestone rings would be fairly continuous in case of a slow rate of denudation and erosion; if broken through by the action of the sea and with a rapid rate of denudation, only disconnected patches, more or less numerous, according to the rate of erosion, would indicate the former ring; and finally, with a very rapid denudation and erosion, both of the exterior face and interior of the lagoon, or sound, nothing would be left of the elevated mass except the submerged reef-ring. This becomes still more complicated when the limestone mass, while elevated, has been broken through by the underlying volcanic rocks, and when they have displaced portions of the coralliferous limestone beds and left them more accessible to the effects of denudation and of erosion, especially when this action has taken place on the outer face of the elevated mass, and left broken cuts and openings forming connections between the outer sea and the interior basins, which would thus soon be transformed into great sounds or lagoons. The erosive as well as the solvent action of the sea would soon level the outer rim to the plane of the sea level, the further disintegration being stopped by the growth of recent corals or of coralline algæ upon the surface of the coralliferous or massive limestone eroded to the level of the sea or below it. With the more rapid erosion and denudation, both atmospheric and marine, of the limestones, they would rapidly disappear, and there would be left only the volcanic mass which had uplifted the limestones, with here and there a remnant of them to indicate the probable course of events. Of course, when the volcanic masses come up without elevating any limestone beds the conditions are much simpler, and it becomes only a question of the mode of formation of the recent corals around the base of the elevated volcanic mass.

The want of continuity of the atolls of the eastern Paumotus of the Ellice, Gilbert, and Marshall Islands, their separation by considerable distances and great depths, would seem to preclude the idea of the formation of the Tertiary limestones over great areas. The existence of these limestones on disconnected and isolated islands would suggest the formation of the limestones upon mounds or ridges elevated to very different heights below the surface of the ocean, — these mounds and ridges consisting of volcanic or other rocks elevated by the volcanic agencies which

we know to have been active over very extensive areas of the Pacific from Tertiary times to the present day. Yet in some of the Pacific archipelagos the areas upon which the Tertiary limestones were deposited must have been of considerable extent, as for instance the plateau of the northwestern Paumotus, the plateau of the Tonga Islands, and the plateau upon which the eastern islands of the Fiji Archipelago rise: the so-called Lau or Windward group of Fiji. Conditions similar to those under which the central Pacific Tertiary limestones were deposited must have been of wide geographical range; they appear, in addition, in the Philippines, in the Loyalty, the New Hebrides, and Solomon Islands, in New Caledonia, in the China Sea, at Christmas Island, in the Indian Ocean, in the Red Sea, and in the West Indian area.

We left Guam in time to reach Rota by day, and found that this island also is a mass of elevated coralliferous limestone, the highest cliffs of which reach a height of 800 feet. Perhaps in none of the elevated islands have we been able to observe the terraces of submarine elevation as well as at Rota, especially in the small knob at the southwest point of the peninsula separating Sosanlagh and Sosanjaya bays, which itself is also terraced; no less than seven distinct terraces could be traced. There was no sign of any volcanic outburst except at the northwest point of the island, where both the character of the slope and of the vegetation would seem to indicate a volcanic structure.

It is quite probable that others of the Ladrones, like Saipan and the islands to the south, are composed in part at least of elevated limestone, judging from the hydrographic charts and the sketches which accompany them.[1] On many of the northern Ladrones there are active volcanoes, so that it is very possible that the volcanic outbursts which have pushed through the limestones, or have elevated parts of the islands of the group, are of comparatively recent date.

During the last part of our cruise, from Suva to Guam, the unfavorable weather greatly interfered with our deep-sea and pelagic work; in fact, with the exception of the soundings made to develop as far as practicable the depths in the regions of the various coral-reef groups we visited, we

[1] H. O. Chart No. 1748.

abandoned all idea of carrying out the deep-sea and pelagic work planned for the district between the Gilbert and Marshall and Caroline groups. To our great disappointment hardly any marine work could be accomplished, and our investigations were limited almost entirely to the study of the coral reefs of the regions passed through.

After Mr. Townsend's departure, Dr. Moore continued to collect the birds of the islands where we anchored, and they have brought together a fairly typical collection of the avifauna of the South Sea Islands. Dr. Pryor collected the characteristic plants, and Dr. Mayer the insects and reptiles, in addition to such pelagic work as could be done in port. My private assistants, Dr. W. McM. Woodworth and Dr. A. G. Mayer, as well as my son Maximilian, took a large number of photographs, and we must have at least 900 views illustrating the coral reefs of the Pacific. Dr. Woodworth also collected incidentally such ethnological material as could readily be obtained during our short stay at different places.

We were everywhere received with the greatest cordiality and courtesy: by the Governor of the Paumotus, the King of Tonga, Sir George O'Brien (the High Commissioner of the Western Pacific at Suva), Mr. E. Brandeis (the Landes-Hauptmann in charge of the Marshall Islands at Jaluit), the Governor of the Carolines, and the Japanese authorities. The State Department at Washington having kindly asked through the French, English, German, and Japanese Embassies at Washington for the kind offices of the representatives of these nations in Oceania to the "Albatross" while in their respective precincts, thanks to these credentials nothing could exceed the interest shown everywhere in the success of our expedition.

I must also thank Captain Moser and the officers of the "Albatross" for the untiring interest shown by them during the whole time of our expedition in the work of the ship, which was so foreign to the usual duties of a naval officer.

LIST OF THE OFFICERS OF THE UNITED STATES FISH COMMISSION STEAMER "ALBATROSS."

Commander JEFFERSON F. MOSER, U. S. N., *Commanding.*
Lieutenant HUGH RODMAN, U. S. N., *Executive Officer and Navigator.*
Ensign B. K. MCMORRIS, U. S. N., *Chief Engineer.*
" A. J. HEPBURN, U. S. N.
" CYRUS R. MILLER, U. S. N.
" C. S. KEMPFF, U. S. N.
Assistant Surgeon, J. C. PRYOR, U. S. N.
Assistant Pay Master, GREY SKIPWITH, U. S. N.
HARRY CLIFFORD FASSETT, U. S. F. C., *Captain's Clerk.*

SCIENTIFIC STAFF.

CHARLES H. TOWNSEND, *Assistant*, U. S. F. C.
Dr. H. F. MOORE, *Resident Naturalist*, U. S. F. C.
A. B. ALEXANDER, *Fishery Expert*, U. S. F. C.

NOON POSITIONS OF THE UNITED STATES FISH COMMISSION STEAMER "ALBATROSS" DURING HER CRUISE IN THE TROPICAL PACIFIC,

AUGUST, 1899–MARCH, 1900.

SAN FRANCISCO, CALIFORNIA, TO NUKUHIVA, MARQUESAS ISLANDS.

Date. 1899.	Time.	Distance in Miles Noon to Noon.	Position.
Aug. 23	6 06 P.M.		Left San Francisco, California.
24	Noon.	132	35° 53′ N. 123° 29′ W.
25	Noon.	183	32° 57′ 124° 28′
26	Noon.	154	30° 30′ 125° 16′
27	Noon.	158	28° 30′ 127° 01′
28	Noon.	144	26° 37′ 128° 40′
29	Noon.	156	24° 33′ 130° 24′
30	Noon.	166	22° 17′ 132° 13′
31	Noon.	149	20° 12′ 133° 37′
Sept. 1	Noon.	147	18° 16′ 135° 05′
2	Noon.	120	16° 40′ 136° 14′
3	Noon.	129	14° 34′ 136° 41′
4	Noon.	158	11° 59′ 137° 19′
5	Noon.	147	9° 57′ 137° 47′
6	Noon.	105	8° 08′ 137° 37′
7	Noon.	115	6° 30′ 137° 00′
8	Noon.	123	4° 24′ 136° 55′
9	Noon.	120	2° 27′ 137° 22′
10	Noon.	112	1° 00′ 138° 00′
11	Noon.	145	1° 27′ S. 138° 01′
12	Noon.	157	4° 03′ 138° 30′
13	Noon.	155	6° 35′ 138° 59′
14	Noon.	145	8° 39′ 139° 42′
15	9.30 A.M.	48	Arrived at Taï-o-haé, Nukuhiva Island, Marquesas Group.

MARQUESAS ISLANDS TO TAHITI, SOCIETY ISLANDS, VIA NORTHWESTERN PAUMOTUS.

Sept. 17	12.30 P.M.		Left Taï-o-haé, Nukuhiva Island, Marquesas Group.
18	Noon.	152	10° 33′ S. 142° 02′ W.
19	Noon.	168	12° 15′ 144° 15′
20	Noon.	135	13° 50′ 145° 53′
21	10.05 A.M.	141	Arrived at Avatoru Pass, Rangiroa Island, Paumotu Group.
24	6.40 A.M.		Left Avatoru Pass, Rangiroa Island, Paumotu Group.
	10.00 A.M.–3.41 P.M.		Coasting off Rangiroa Island.
	Noon.	25	15° 00′ S. 148° 02′ W.

Date, 1899.	Time.	Distance in Miles Noon to Noon.	Position.
Sept. 25	8.00–9.48 A.M.		Coasting off Tikehau Island.
	Noon.	102	15° 01′ S. 148° 29′ 30″ W.
	2.30–6.00 P.M.		Coasting off Matahiva Island.
26	11.28 A.M.	104	Arrived at Makatea Island.
	6.00 P.M.		Left Makatea Island.
27	Noon.	132	17° 23′ S. 149° 24′ W.
	3.45 P.M.	8	Arrived at Papeete, Tahiti.
	THROUGH THE PAUMOTU ARCHIPELAGO.		
Oct. 5	6.00 A.M.		Left Papeete, Tahiti.
	Noon.	17	17° 18′ S. 149° 31′ W.
	1.30–2.30 P.M.		Coasting off Tetiaroa Island.
6	7.45 A.M.	122	Arrived at Makatea Island.
	3.07 P.M.		Left Makatea Island.
7	8.37 A.M.	122	Arrived at Niau Island.
	Noon.		Left Niau Island.
	5.20 P.M.		Arrived Pakaka Pass, Apataki Island.
8	9.45 A.M.		Left Pakaka Pass, Apataki Island.
	Noon.	59	15° 24′ S. 146° 25′ W.
9	Noon.	109	14° 57′ 144° 40′
	12.55 P.M.		Arrived at Tikei Island.
	11.15 P.M.		Left Tikei Island.
10	8.30 until 10.45 A.M.		Coasting off Kauehi Island.
	Noon.	106	16° 00′ S. 145° 19′ W.
	3.30 P.M.	30	Arrived at Rotoava, Fakarava Island.
14	7.00 A.M.		Left Rotoava, Fakarava Island.
	Noon.	22	16° 09′ S. 145° 49′ W.
15	9.00 A.M. until		Coasting off Anaa Island.
	Noon.	109	
15	7.40 P.M. until		Lying to and coasting off Tahanea Island.
16	11.05 P.M.		
	Noon.	101	16° 47′ S. 144° 40′ W.
	3.40–4.05 P.M.		Coasting off Tuanaka Island.
17	Noon.	151	15° 56′ S. 142° 30′ W.
	1.00–2.00 P.M.		Coasting off Raroia Island.
17	2.50 P.M. until		Lying to and coasting off Takume Island.
18	5.30 A.M.		
	8.00–11.35 A.M.		Coasting off Raroia Island.
	Noon.	85	16° 11′ S. 142° 37′ W.
18	4.30 P.M. until		Lying to and coasting off Taenga Island (Hepuhepuarua Anchorage).
19	2.30 A.M.		
	11.50 A.M.	98	Arrived at Makemo Lagoon.
25	4.35 P.M.		Left Makemo Lagoon.
26	8.07–9.40 A.M.		Coasting off Tekokoto Island.
	Noon.	92	17° 33′ S. 142° 41′ W.
	1.20 P.M.		Arrived at Hikueru Island.
27	Noon.	16	Off Hikueru Island.
	6.18 P.M.		Left Hikueru Atoll.
28	5.55 A.M. until		Lying to and coasting off Marokau Island.
	5.20 P.M.		
	Noon.	51	Off West coast Marokau Island.
29	6.19 A.M. until		Lying to and coasting off Hao Island.
	6.15 P.M.		
	Noon.	89	Off West coast Hao Island.

Date. 1899.	Time.	Distance in Miles Noon to Noon.	Position.
Oct. 30	10.30 A.M. until 8.10 P.M.		Lying to and coasting off Akiaki Island.
	Noon.	113	Off West coast Akiaki Island.
31	7.28 A.M. until 12.05 P.M.		Lying to and coasting off Nukutavake Island.
	Noon.	64	S. W. point Nukutavake Island.
	1.40 P.M. until 5.35 P.M.		Lying to and coasting off Pinaki Island.
Nov. 1	Noon.	131	19° 50′ 30″ S. 140° 33′ W.
2	10.23 A.M. until 11.30 A.M.		Coasting off Nukutipipi Island.
	Noon.	160	20° 42′ S. 143° 03′ W.
	2.10–3.30 P.M.		Coasting off Anu-Anurunga Island.
	6.12–6.50 P.M.		Coasting off Anu-Anuraro Island.
3	9.30 A.M. until 1.50 P.M.		Lying to and coasting off Hereheretue Island.
	Noon.	131	Off West coast Hereheretue Island.
4	Noon.	105	18° 55′ S. 146° 32′ W.
5	8.30 A.M. until 12.20 P.M.		Lying to and coasting off Mehetia Island.
5	Noon.	108	Off N. W. coast Mehetia Island.
6	11.50 A.M.	126	Arrived at Papeete, Tahiti.

SOCIETY ISLANDS TO TONGATÁBU, TONGA ARCHIPELAGO, VIA LEEWARD, SOCIETY, AND COOK GROUPS, AND NIUE ISLAND.

Nov. 15	10.40 A.M.		Left Papeete, Tahiti.
	Noon.	8	17° 29′ S. 149° 43′ W.
	2.30–8.51 P.M.		Lying to and coasting off Murea Island.
16	8.00–10.00 A.M.		Coasting off Huaheine Island.
	Noon.	112	16° 38′ S. 151° 18′ W.
	6.10 P.M.		Arrived at Hurepiti Bay, Tahaa Island.
17	6.15 A.M.		Left Hurepiti Bay, Tahaa Island.
	11.40 A.M.	26	Arrived at Bora Bora Island.
18	7.10 A.M.		Left Bora Bora Island.
	9.30–10.20 A.M.		Coasting off Motu Iti.
	Noon.	27	16° 22′ S. 152° 03′ W.
	2.30–3.00 P.M.		Coasting off Maupiti Island.
19	Noon.	146	17° 12′ S. 154° 21′ W.
20	Noon.	156	17° 48′ 157° 00′
21	11.20 A.M.	176	Arrived off North coast Aitutaki Island.
	5.47 P.M.		Left Aitutaki Island.
22	Noon.	156	18° 54′ S. 162° 26′ W.
23	Noon.	154	19° 00′ 165° 00′
24	Noon.	155	19° 04′ 167° 41′
25	10.15 A.M.	137	Arrived off Alofi Village, Niue Island.
	6.20 P.M.		Left Alofi Village, Niue Island.
26	Noon.	136	20° 10′ S. 171° 54′ W.
27	Noon.	114	21° 18′ 173° 34′
28	7.10–11.15 A.M.		Coasting off Eua Island.
	11.15 A.M.	105	Arrived English Roads (Ohonua village), Eua Island.
29	6.20 A.M.		Left English Roads (Ohonua village), Eua Island.
	9.23 A.M.	26	Arrived Nukualofa, Tongatábu Island, Tonga Islands.

THROUGH TONGA ARCHIPELAGO, AND TO SUVA, FIJI ARCHIPELAGO.

Date. 1899.	Time.	Distance in Miles Noon to Noon.	Position.
Dec. 1	7.00 A.M.		Left Nukualofa, Tongatábu Island, Tonga Islands.
	Noon.	34	21° 38′ S. 175° 06′ W.
	5.15 P.M.	28	Arrived at Nomuka Island.
3	12.30 P.M.		Left Nomuka Island.
4	9.10 A.M.	119	Arrived at Neiafu, Vavau Group, Tonga Islands.
5	4.15 P.M.		Left Neiafu, Vavau Group, Tonga Islands.
6	Noon.	152	18° 43′ S. 176° 31′ W.
7	Noon.	140	18° 56′ 178° 49′
	2.20 P.M.		Arrived at Kambara Island, Fiji.
8	Dropped.		
9	7.25 A.M.		Left Kambara Island, Fiji.
	Noon.	42	18° 58′ S. 179° 31′ W.
10	7.25 A.M.	147	Arrived at Suva, Fiji.

FIJI ISLANDS, THROUGH ELLICE AND GILBERT CHAINS, TO JALUIT, MARSHALL ARCHIPELAGO.

Dec. 19	9.15 A.M.		Left Suva, Fiji.
	Noon.	22	18° 10′ S. 178° 42′ E.
20	Noon.	180	16° 11′ 179° 08′ W.
21	Noon.	195	13° 00′ 179° 42′
22	Noon.	136	Off Nurakita Island, Ellice Group.
23	Noon.	154	Off North coast Funafuti Island, Ellice Group.
23	2.20 P.M.	10	Arrived at Fongafale, Funafuti Island.
26	6.20 A.M.		Left Fongafale, Funafuti Island.
	Noon.	42	8° 09′ S. 178° 42′ E.
	2.45–4.45 P.M.		Coasting off Nukufetau Island.
27	Noon.	150	6° 10′ S. 177° 20′ E.
	12.30 P.M.		Ran past Niutao Island.
28	Noon.	76	4° 52′ S. 176° 54′ E.
29	Noon.	137	South shore of Arorai Island, Gilbert Group.
	7.00 P.M.		Left Arorai Island.
30	Noon.	94	1° 43′ S. 175° 48′ E.
31	3.30–7.00 P.M.		Lying to off South coast of Onoatoa Atoll.
	11.20 A.M. until 2.50 P.M.		Coasting off Taputeuea Atoll.
	Noon.	130	Off N. E. coast Taputeuea Atoll.
1900			
Jan. 1	Noon.	156	00° 35′ N. 174° 02′ E.
	12.20–10.00 P.M.		Lying to and coasting off Apamama Atoll.
2	11.20 A.M. until Noon.		Coasting off Maiana Atoll.
	Noon.	98	Off N. E. point Maiana Atoll.
2	5.00 P.M. until		Lying to off South coast Tarawa Atoll.
3	9.45 A.M.		
3	Noon.	40	1° 17′ N. 173° 09′ E.
	1.00–5.00 P.M.		Coasting along Tarawa Atoll.
	6.15 P.M. until		Lying to off South coast Apaiang Atoll.
4	8.00 A.M.		
	Noon.	55	1° 56′ N. 173° 16′ E.
	1.00–8.00 P.M.		Lying to and coasting off Maraki Atoll.

Date. 1900.	Time.	Distance in Miles Noon to Noon.	Position.
Jan. 5	7.50 A.M.–Noon.		Coasting off South coast Taritari Atoll.
	Noon.	111	Off Entrance, West coast Taritari Atoll.
	1.20 P.M.	8	Arrived at Butaritari, Taritari Atoll.
7	7.30 A.M.		Left Butaritari, Taritari Atoll.
	Noon.	31	3° 27′ N. 172° 33′ E.
8	Noon.	120	4° 34′ 171° 55′
9	Noon.	124	Off S. E. Coast Jaluit Island, Jaluit Atoll, Marshall Islands.
	1.24 P.M.	8	Arrived at Jaluit, Jaluit Atoll.
THROUGH MARSHALL ARCHIPELAGO.			
Jan. 14	10.00 A.M.		Left Jaluit, Jaluit Island.
	Noon.	24	Off Pingelap Island, Jaluit Atoll.
15	9.00 A.M. Noon.		Coasting off Elmore Atoll.
	Noon.	113	Off Wotje Island, Elmore Atoll.
	5.20–6.00 P.M.		Coasting off Namu Atoll.
16	8.00 A.M. until 8.00 P.M.		Coasting off Kwajalong Atoll.
	Noon.	132	Off Legan Island, Kwajalong Atoll.
17	Noon.	153	10° 52′ N. 166° 55′ E.
	4.30 P.M.		Arrived at Rongelappelap Island, Rongelab Atoll.
18	10.35 A.M.		Left Rongelappelap Island.
	Noon.	32	Off South Pass, Rongelab Atoll.
19	Noon.	105	10° 12′ N. 168° 11′ E.
20	8.10 A.M. until 1.00 P.M.		Coasting off Likieb Atoll.
	Noon.	80	Off S. W. Point Likieb Atoll.
	1.47 P.M.		Arrived at Likieb Island, Likieb Atoll.
21	9.00 A.M.		Left Likieb Island, Likieb Atoll.
	Noon.	33	9° 43′ N. 169° 26′ E.
	6.04 P.M.		Arrived Rurick Pass, Wotje Atoll.
22	8.15 A.M.		Left Rurick Pass, and coasted off Wotje Atoll.
	Noon.	54	Off Schischmarev Island, Wotje Atoll.
	1 40 P.M.		Arrived at Wotje Island Anchorage, Wotje Atoll.
23	8.00 A.M.		Left Wotje Island Anchorage, Wotje Atoll.
	Noon.	26	9° 12′ N. 170° 13′ E.
24	Noon.	147	Off N. W. Point Arhno Atoll.
	Noon–1.45 P.M.		Coasting off Arhno Atoll.
	3.15 P.M.	19	Arrived at Arhno Lagoon.
28	8.30 A.M.		Left Arhno Lagoon.
	10.00 A.M. until 2.40 P.M.		Coasting off Arhno Atoll.
	Noon.	24	Off N. W. Point Arhno Atoll.
29	Noon.	158	Off S. E. Pass, Jaluit Atoll.
	1.27 P.M.	8	Arrived at Jaluit, Jaluit Atoll.
MARSHALL ISLANDS, THROUGH CAROLINE ISLANDS TO GUAM, LADRONE ISLANDS, AND TO YOKOHAMA, JAPAN.			
Feb. 5	10.25 A.M.		Left Jaluit, Jaluit Atoll.
	Noon.	15	Off S. W. Pass Jaluit Atoll.
6	Noon.	195	5° 27′ N. 166° 30′ E.

Date. 1900.	Time.	Distance in Miles Noon to Noon.	Position.
Feb. 7	Noon.	184	5° 31′ 163° 26′
	6.30 P.M.	37	Arrived at Port Lottin, Kusaie Island, Caroline Islands.
9	1.25 P.M.		Left Port Lottin, Kusaie Island.
10	Noon.	147	6° 09′ N. 160° 50′ E.
	1.00–2.00 P.M.		Lying to off Pingelap Islands.
11	Noon.	155	6° 47′ N. 158° 14′ E.
	3.45 P.M.	25	Arrived at Kiti Harbor, Ponapi Island.
12	12.50.		Left Kiti Harbor, Ponapi Island.
13	Noon.	138	6° 53′ N. 156° 00′ E.
14	Noon.	159	6° 55′ 153° 26′
	6.50 P.M.–Midnight.		Lying to off Namo Island.
	Noon.	110	7° 06′ N. 151° 46′ E.
	4.55 P.M.	28	Arrived at Uola Island, Truk Group.
17	2.00		Left Uola Island, Truk Group.
18	9.10 A.M. until		Coasting along Namonuito Group.
	2.25 P.M.		
	Noon.	131	Off Onoupe Island, Namonuito Group.
19	Noon.	151	10° 34′ N. 148° 25′ E.
20	Noon.	176	12° 23′ 146° 26′
21	Noon.	135	Off Agaña, Guam.
	1.55 P.M.	10	Arrived at San Luis d'Apra, Guam.
25	8.25 A.M.		Left San Luis d'Apra, Guam.
	Noon.	25	13° 48′ N. 144° 54′ E.
	2.30–3.09 P.M.		Coasting off Rota Island.
26	Noon.	204	17° 07′ N. 144° 45′ E.
27	Noon.	220	20° 46′ 144° 24′
28	Noon.	210	24° 15′ 144° 02′
March 1	Noon.	197	27° 28′ 143° 40′
2	Noon.	212	30° 53′ 142° 47′
3	Noon.	185	33° 28′ 140° 41′
4	10.00 A.M.	140	Arrived at Yokohama, Japan.
		15,122	

LIST OF THE STATIONS

OCCUPIED BY THE U. S. F. C. S. "ALBATROSS," DURING HER CRUISE IN THE TROPICAL PACIFIC,

AUGUST, 1899–MARCH, 1900.

SAN FRANCISCO, CALIFORNIA, TO NUKUHIVA, MARQUESAS ISLANDS.

Serial Number.	Date. 1899.	Position.		Temperatures.		Depth in Fathoms.	Nature of Bottom.	Remarks.
		Latitude North.	Longitude West.	Surface.	Bottom.			
		° ′	° ′	°	°			
1	Aug. 26	31 10	125 00	63	. .	1955	. . . . .	Lost thermometer and detacher; 320 miles from Point Conception.
2	Aug. 27	28 23	126 57	66	34.6	2368	Red clay. Light brown ooze.	450 miles from Guadalupe Island, 500 miles from Point Conception. Large haul of manganese nodules, sharks' teeth, and cetacean bones.
3	Aug. 28	26 18	128 54	68	. .	. .	. . . . .	. . . . .
4	Aug. 29	24 45	130 16	69	34.6	2628	Light brown ooze, same as at St. 2. Red clay.	. . . . .
5	Aug. 30	22 42	131 54	70	34.6	2740	Light brown ooze, same as at St. 2. Red clay.	Too rough to trawl; distant from Guadalupe Island 800 miles, from Point Conception 960 miles.
6	Aug. 31	20 26	133 28	75	. .	2810	Dark brown mud ooze. Red clay.	Distant from Guadalupe Island 960 miles, from Sebastian Viscaino 1060 miles.
7	Sept. 1	18 19	134 57	76	. .	2881	Red clay. Dark brown ooze. Very sticky.	. . . . .
8	Sept. 2	17 13	136 09	78	. .	2766	. . . . .	. . . . .
9	" "	16 52	136 12	76	. .	3003	. . . . .	. . . . .
10	" "	16 38	136 14	78	. .	3088	. . . . .	Deepest part of Moser Basin.
11	Sept. 3	14 38	136 44	79	. .	2646	Red clay.	Passing out of deepest part of Moser Basin.
12	Sept. 4	12 07	137 18	81	. .	2883	Red clay, radiol.	. . . . .
13	Sept. 5	9 57	137 47	82	. .	2690	Red clay. Light brown ooze, coarse mineral particles. Radiolarian ooze.	Large balls of manganese nodules, cetacean bones, sharks' teeth.
14	Sept. 7	6 41	137 00	82	. .	2776	Gray ooze glob. Foram. no radiolarians. Not sticky.	. . . . .
15	Sept. 8	4 35	136 54	79	. .	2583	Fine gray ooze. Radiolarians.	. . . . .
16	Sept. 9	2 38	137 22	79	35.2	2440	Light yellow gray glob. ooze.	To Hawaiian Islands 1500 miles, to Marquesas 660 miles.
17	Sept. 10	0 50	137 54	79	. .	2463	Light yellow gray glob. ooze.	Sea too heavy to sound after this till Sept. 13.

Serial Number.	Date. 1899.	Position. Latitude South.	Position. Longitude West.	Temperatures. Surface.	Temperatures. Bottom.	Depth in Fathoms.	Nature of Bottom.	Remarks.
		° ′	° ′	°	°			
18	Sept. 13	6 25	138 59	80	35	2475	Light gray yellow ooze. Globig. ooze. Radiolarian.	About 175 miles to Marquesas. Stations 1–18 referred to H. O. Chart No. 527, corrected to April, 1897.
19	" "	7 58	139 09	79	. .	2287	Coarse glob. ooze.	Stations 19 to 29 referred to H. O. Chart No. 1797, edition of May, 1899.
20	Sept. 14	8 13	139 10	79	35.1	2267	Glob. ooze with volcanic particles.	. . . . .
21	" "	8 28	139 12	79	. .	2183	Glob. ooze. Many volcanic particles.	. . . . .
22	" "	8 31	139 26	79	. .	1939	Glob. ooze. Fine volcanic particles.	. . . . .
23	" "	8 33	139 36	80	35.5	1802	Gray ooze. Glob. and Radiol. and coarse volcanic particles.	Globigerinae still retaining their color. Developing the Marquesas Plateau.

MARQUESAS ISLANDS TO TAHITI, SOCIETY ISLANDS, VIA NORTHWESTERN PAUMOTUS.

Stations in Vicinity of the Marquesas Islands.

		° ′	° ′	°	°			
24	Sept. 14	8 41	139 46	80	. .	1040	Coarse glob. ooze. Volcanic particles.	15½ miles N. 43° W., same as below.
25	" "	8 48	139 48	80	38	830	Globig. and volcanic mud and fragments.	13 miles N. 73° W. of Haunanu Point, Ua Huka Island.
26	" "	8 52	139 52	80	. .	1173	Glob. ooze. Pteropods and volcanic particles.	17 miles west of Mt. Uranupe, Nukuhiva Island (Taï o haé).
27	Sept. 15	9 01	140 04	79	. .	687	Glob. ooze. Volcanic particles.	6 miles S. 20° E. of Anna Maria Bay.
28	Sept. 17	9 05	140 13	80	. .	1284	Rocky. Volcanic fragments.	About 18 miles S. 13° W. of Chichakoff Point.

Stations from the Marquesas to Rangiroa.

		° ′	° ′	°	°			
29	Sept. 17	9 16	140 25	80	34.9	1932	Light yellow gray glob. ooze. Coarse volcanic particles.	25 miles from Cape Chichakoff, Nukuhiva, 20 miles from Ua pu Island.
30	Sept. 18	10 29	141 52	81	35	2456	Light gray glob. Few Radiol. Volcanic particles.	Stations 30, 31 referred to H. O. Chart No. 824[a], Oct. 1888.
31	Sept. 19	12 20	144 15	80	35	2700	Red clay.	Deepest part of Channel separating the Marquesas from the Paumotus.
32	Sept. 20	13 37	145 42	80	35	2451	Red clay with Foram.	Stations 32–35 referred to H. O. Chart No. 77, corrected to 1899.
33	" "	14 10	146 10	81	35.1	2527	Red clay.	22 miles N. 28° E. of entrance to Ahii.
34	" "	14 26	146 25	81	. .	1208	Very light col. glob. ooze.	About 2½ miles northwest of entrance to Ahii.
35	Sept. 21	14 42	147 08	80	. .	1462	Fine coral sand glob.	Position according to H. O. Chart No. 77.

Serial Number.	Date. 1899.	Position.		Temperatures.		Depth in Fathoms.	Nature of Bottom.	Remarks.
		Latitude South.	Longitude West.	Surface.	Bottom.			
		RANGIROA TO TIKEHAU AND TO MATAHIVA.						
		° ′	° ′	°	°			
36	Sept. 21	14 45	147 38	80	. .	706	Volcanic rock fragments.	Stations 32–35 referred to H. O. Chart No. 77, corrected to 1899. Distant 16 miles northeast of Avatoru Pass, Rangiroa, according to H. O. Chart No. 77. Stations 36 to 60 referred to H. O. Chart No. 85, corrected to 1891.
37	Sept. 24	. . .	. . . .	80	. .	112	Coral sand.	$\frac{5}{8}$ mile from Beacon at the entrance to Avatoru Pass. Stations 37 to 42. Running a line N., normal in continuation of Avatoru Pass.
38	" "	. . .	. . . .	80	. .	604	Broken shells and sea-urchins. Pteropods. Glob. Rad. Mineral particles.	$1\frac{5}{8}$ miles from Beacon, entrance to Avatoru Pass.
39	" "	. . .	. . . .	80	. .	645	Fine coral sand, glob. ooze. Broken shells Mineral particles.	Same line, 1 mile farther north.
40	" "	. . .	. . . .	80	. .	661	Coral sand. Glob Pteropods. A few Radiolarians.	Same line, 1 mile farther north.
41	" "	. . .	. . . .	81	. .	684	Coral sand. Glob. and volcanic particles.	2 miles farther north, same line.
42	" "	. . .	. . . .	81	. .	819	Coral sand. Glob. Volcanic particles.	$2\frac{1}{2}$ miles farther north. Same line. About 8 miles north, off Avatoru entrance. St. 35 was about 25 miles at right angles to Rangiroa, and showed a depth of 1462 fathoms, the edge of plateau being between it and St. 36.
43	" "	15 13	147 53	82	. .	341	Coarse coral sand.	About $\frac{3}{4}$ mile from Reef off south shore Rangiroa.
44	" "	. . .	. . . .	82	. .	391	Coarse coral sand.	1 mile from south shore, Rangiroa.
45	" "	. . .	. . . .	82	. .	524	Coarse coral sand, broken shells. Pteropods, glob. ooze.	1 mile from last station. Normal to coast.
46	" "	. . .	. . . .	80	. .	450	Pteropod ooze, coral sand, small manganese nodules, round grains of coral sand.	2 miles from last station. Positions of St. 43 to 60 approximate, referred to H. O. Chart No. 85, as corrected by "Albatross."
47	" "	. . .	. . . .	82	. .	764	Coral sand, volcanic or manganese particles. Glob.	3 miles from last station.
48	" "	. . .	. . . .	80	. .	897	Glob. Foram. Pteropods. Manganese or lava particles.	5 miles from last station, 11 m. S. 15° W. of Station 44.
49	" "	15 25	148 08	80	. .	1123	Coral sand, manganese (?) particles. Globigerinae.	. . . . .
50	Sept. 25	15 25.5	148 24.4	80	. .	1486	Glob. ooze. Manganese particles (?).	. . . . .
51	" "	15 02	148 24	80	. .	488	Coarse coral sand. Glob.	1 mile from shore of Tikehau, going towards Matahiva.

Serial Number.	Date. 1899.	Position.		Temperatures.		Depth in Fathoms.	Nature of Bottom.	Remarks.
		Latitude South.	Longitude West.	Surface.	Bottom.			
		° ′	° ′	°	°			
52	Sept. 25	15 01.4	148 25	80	. .	670	Coarse coral sand, broken shells and glob.	1 mile from last position. This sounding is deeper than one off Rangiroa at same distance from shore.
53	" "	. . .	. . . .	81	. .	782	Pteropod ooze. Glob. Manganese particles (?).	2 miles from last position.
54	" "	. . .	. . . .	81	. .	850	Pteropod ooze, few globig.	3 miles from last position. Same normal.
55	" "	. . .	. . . .	81	. .	844	Globig. ooze, small manganese nodules.	5 miles from last position. Same normal.
56	" "	14 56	148 44	81	. .	711	Pteropod ooze, fine coral sand. Globig. ooze. Small manganese nodules.	8 miles from last position. Same normal. Changed course to go round the north side of the Island of Matahiva.
57	" "	. . .	. . . .	80	. .	486	Coarse coral sand. Volcanic (?) particles. Manganese (?)	3 miles from last station, going north.
58	" "	. . .	. . . .	80	. .	621	Coarse coral sand.	$2\frac{1}{2}$ miles off west shore of Matahiva.
59	" "	. . .	. . . .	80	. .	860	Glob. ooze. Coral sand. Volcanic (?) particles.	4 miles off southwest shore of Matahiva.
60	" "	. . .	. . . .	80	. .	1257	Coarse coral sand. Globigerinae. Volcanic (?) particles.	Off south shore of Matahiva, about $7\frac{1}{2}$ miles farther off shore than St. 59.
							MATAHIVA TO MAKATEA AND TO PAPEETE, TAHITI ISLAND.	
		° ′	° ′	°	°			
61	Sept. 25	15 16	148 46	79	. .	1762	Lightgrayglob.ooze.	St. 61 to 180 referred to H. O Chart No. 77, corrected to 1899.
62	Sept. 26	15 33	148 45	80	. .	2267	Glob. ooze and mud (volcanic?), allied to red clay.	On way to Makatea.
63	" "	15 42	148 44	80	. .	2247	Globigerinae and mud allied to red clay.	. . . . .
64	" "	15 51	148 15	80	. .	581	Coarse coral sand.	About $1\frac{3}{10}$ miles off the bluff on west side of central part of Makatea.
65	" "	15 57.3	148 18.8	80	. .	1363	Coarse coral sand. Small manganese nodules.	5 miles south of Makatea. This is the first of a line of soundings from Makatea to Tahiti. St. 65 to 72.
66	" "	16 10	148 26	80	. .	2238	Volcanic mud. Manganese nodules. Globigerinae.	. . . . .
67	Sept. 27	16 32	148 40	80	. .	2363	Volcanic mud. Globigerinae.	. . . . .
68	" "	16 57	148 58	79	. .	2224	Coarse volcanic mud. Globigerinae.	. . . . .
69	" "	17 14	149 10	80	. .	1930	. . . . .	20 miles from last station.
70	" "	17 21	149 15	80	. .	1585	Fine volcanic mud, yellow brown.	10 miles from last station.
71	" "	17 25.3	149 26	81	. .	775	Coarse volcanic mud. Manganese(?) nodule.	$4\frac{1}{2}$ miles N. 32° E. from Point Venus. 6 miles from last station.
72	Sept. 27	17 26.5	149 32.4	79	. .	867	Fine volcanic sand. Coral sand. Globigerinae.	4 miles N. 54° W. from Point Venus. 6 miles from last station.

THROUGH THE PAUMOTU ARCHIPELAGO.

TAHITI TO MAKATEA VIA TETIAROA.

Serial Number.	Date. 1899.	Position. Latitude South.	Position. Longitude West.	Temperatures. Surface.	Temperatures. Bottom.	Depth in Fathoms.	Nature of Bottom.	Remarks.
		° ′	° ′	°	°			
73	Oct. 5	17 27	149 32	79	. .	807	Fine volcanic sand. Pteropods.	3.8 miles N. 55° W. from Point Venus.
74	" "	17 28.4	149 34	79	. .	. . .	. . . . .	4.8 miles N. 82° W. from Point Venus. Drifted, while trawling, from St. 73 to 74.
75	" "	16 57	147 29	80	. .	1592	Volcanic mud mixed with globigerinae.	Tetiaroa distant 6 miles.

MAKATEA TO APATAKI VIA NIAU.

		° ′	° ′	°	°			
76	Oct. 6	15 56.2	147 40	80	35	2269	Light brown volcanic mud and glob. ooze.	St. 76 to 81. Line from Makatea to Niau.
77	Oct. 7	16 03	147 11	79	36	1322	Glob. ooze. Volcanic particles.	. . . . .
78	" "	16 08	146 42	79	39	609	Glob. ooze.	About 10 miles off Niau.
79	" "	16 10	146 23	79	. .	252	Coral sand and globigerinae.	About ¾ mile off shore, Niau.
80	" "	16 11.5	146 25	80	. .	491	Pteropod ooze. Globigerinae.	1.75 miles off shore, southwest of village, Niau.
81	" "	15 54.5	146 20	80	. .	677	Coral sand. Glob. ooze.	14 miles from Niau, bearing S. 3° E. About 10 miles from Kaukura N. 14° W.
82	" "	15 42	146 20	80	. .	675	Pteropod ooze.	In triangle Apataki, distant N. 6 miles; Kaukura, S. 60° W., distant 9 miles; Toao, N. 81°, distant about 12 miles.
83	" "	15 34	146 26	80	. .	333	. . . . .	½ mile S. 45° W. from Pakaka entrance to Apataki.
84	Oct. 8	15 35.8	146 27.5	79	39.4	613	Coral sand. Glob. Broken shells. Pteropods.	Off Apataki Entrance, about 2 miles S. 50° W.
85	" "	15 34.3	146 28	80	. .	520	Coral sand.	About 1 mile S. 55° W. of Pakaka Entrance.

APATAKI TO TIKEI.

		° ′	° ′	°	°			
86	Oct. 8	15 18.3	146 23	80	38.8	654	Coarse coral sand.	First of a line to Tikei. About 1 mile from northwest corner of Apataki.
87	" "	15 15	146 07	80	. .	1364	Glob. ooze. Few volcanic particles.	About 7 miles N. 45° E. off northeast point of Apataki.
88	Oct. 9	14 57	144 34	80	. .	360	Coarse coral sand. Pteropod shells.	½ mile off west shore of Tikei where landed.

NGARUAE PASS, FAKARAVA TO TAKUME VIA ANAA AND TAHANEA.

		° ′	° ′	°	°			
89	Oct. 14	16 03.5	145 43	80	. .	599	Coarse coral sand.	About 1 mile N. 28° W. of north entrance to Fakarava. First of line of soundings in continuation of Ngaruae Pass.

Serial Number.	Date. 1899.	Position.		Temperatures.		Depth in Fathoms.	Nature of Bottom.	Remarks.
		Latitude South.	Longitude West.	Surface.	Bottom.			
		° ′	° ′	°	°			
90	Oct. 14	16 02	145 43.5	80	. .	666	Coarse coral sand. Pteropods.	About 3 miles farther north than last station. 3½ miles N. 35° W. from Ngaruae Pass.
91	" "	16 38	145 31	80	. .	602	Coarse coral sand. Pteropod ooze.	About 2 miles due S.W. from southwest Point of Fakarava.
92	" "	16 44	145 35	80	. .	839	Coral coated with manganese.	⅚ mile farther than Station 91.
93	" "	16 51	145 42	80	35.7	1300	Glob. ooze.	10 miles farther than 92. Line to Anaa at first 40 miles to S.W., then 30 miles to north side of Anaa.
94	" "	16 57	145 49	79	. .	1531	Fine volcanic mud and globigerinae.	10 miles from Station 93.
95	Oct. 15	17 09	146 00	78	36.10	1079	Glob. ooze.	Changed course toward Anaa at this station.
96	" "	17 14.5	145 49	77	39.7	527	Coral frgts. covered with manganese.	. . . . .
97	" "	17 17	145 45.5	79	. .	804	Globig. ooze and many very small manganese nodules.	6 miles from Station 96.
98	" "	17 21	145 41	79	. .	642	Pteropod ooze. Manganese nodules on coral sand.	Off Anaa, 6 miles from Station 97.
99	" "	17 22	145 37	79	39	568	Manganese nodules. Coarse coral sand.	About 1 3/10 miles off northwest face of Anaa.
100	" "	17 20	145 31	80	. .	225	Coral sand.	About ¼ mile to edge of reef off village at entrance to lagoon of Anaa.
101	" "	17 16	145 27	80	36	1110	Pteropod ooze. Fine coral sand. Manganese nodules.	About 5 miles N. 50° E. off Anaa Entrance. This is first of a line of soundings across to Tahanea. St. 101 to 106.
102	" "	17 10	145 19	82	36	1679	Light yellowish brown globig. ooze.	. . . . .
103	" "	17 03	145 08.5	82	35.1	1733	White glob. ooze.	15 miles from Station 102.
104	" "	16 55	145 03	81	. .	966	White glob. ooze. Few manganese nod. grains.	About 10 miles from Station 103, 4 miles W.S.W. from southwest point of Tahanea.
105	" "	16 53	145 00	80	38.6	654	Very small manganese nodules. Coral sand.	About 2 miles W. of southwest point of Tahanea.
106	Oct. 16	16 55	144 56	80	. .	269	Coarse coral sand.	About ½ mile off south shore of Tahanea and about 3 miles S. 45° W. of southwest point of Tahanea.
107	" "	16 24	143 59	80	. .	467	White coral sand.	1 mile N.W. of northwest Pass to Makemo on angular line to Raroia.
108	" "	16 20	143 55	80	. .	856	Pteropod ooze. Fine coral sand. Light yellow gray glob Few volcanic particles (?).	4 miles N. of northwest end of Makemo.
109	" "	16 13	143 48	80	. .	987	Pteropod ooze. Glob. Volcanic particles(?).	10 miles north of Station 108.
110	" "	16 03	143 32.5	80	36.3	1084	Light yellow gray glob. ooze.	15 miles north of Station 109.
111	Oct. 17	15 53	143 26	80	35	1805	Light yellow gray glob. ooze.	At next station on line to Raroia changed direction at Station 111.
112	" "	15 54	143 06	80	35.4	1568	Glob. ooze. Light yellow. Manganese.	20 miles from St. 111.

Serial Number.	Date. 1899.	Position.		Temperatures.		Depth in Fathoms.	Nature of Bottom.	Remarks.
		Latitude South.	Longitude West.	Surface.	Bottom.			
		° ′	° ′	°	°			
113	Oct. 17	15 55	142 39	80	. .	1503	Glob. ooze. Light yellow. Manganese.	20 miles from St. 112.
114	" "	15 56	142 29	80	35.7	1385	Glob. ooze. Few manganese particles.	This is about 5 miles from centre of west coast of Raroia.
115	" "	15 56.3	142 29	81	40.2	508	Coarse coral sand. Pteropod ooze.	About ½ mile from the shore at northwest point of Raroia.
116	Oct. 18	15 53	142 14	79	38.7	572	Coarse coral sand.	About 1½ miles off southwest point of Takume.
117	" "	15 54	142 16	79	38	563	Coral sand incrusted with manganese.	Half way between Takume and Raroia.
		TAKUME TO MAKEMO VIA RAROIA AND TAENGA.						
		° ′	° ′	°	°			
118	Oct. 18	16 12	142 31	80	38.2	630	Coarse coral sand. Pteropod ooze and manganeseparticles	About 1 mile off southwest point of Raroia.
119	" "	16 14	142 50	80	35.5	1516	Glob. ooze. Manganese particles.	Half way between Raroia and Taenga.
120	" "	16 21	143 14	80	36.5	928	Glob. and pteropod ooze.	About 3 miles S. 67° W., off southwest face of Taenga.
121	Oct. 19	16 25	143 33	79	36.1	1108	Glob. ooze, a few pteropods, and manganese particles.	About half way to Taenga.
		MAKEMO TO HIKUERU VIA TEKOKOTO.						
		° ′	° ′	°	°			
122	Oct. 20	16 29	143 41	79	39.7	540	Coral sand. Pteropod ooze.	About 1 mile off north shore of Makemo.
123	Oct. 25	16 35	143 31	80	39	603	Coarse coral sand.	About 1 mile off entrance to Makemo.
124	" "	16 42	143 10	79	. .	1221	Glob. ooze. Manganese.	11 miles E. by S. off east point of Makemo, on line to Tekokoto.
125	Oct. 26	16 51	142 57	79	36	1135	Glob. ooze.	Half way between Nihiru and Marutea.
126	" "	17 07	142 49	79	35.9	1235	Glob. manganese.	. . . . .
127	" "	17 20	142 35	79	. .	617	Coral sand.	About 1 mile west from Tekokoto.
128	" "	17 28	142 38	80	36.6	1009	Pteropods and glob. ooze.	Half way to Hikueru from Tekokoto. 6 miles north of centre of Hikueru atoll.
129	Oct. 27	17 35	142 42	80	43.8	348	Coral sand and broken shells.	⅓ of a mile W. of northwest point of Hikueru.
130	" "	17 35	142 44	80	37.8	798	Coral sand. Pteropod ooze.	1⅓ mile west of last station. Same normal.
		HIKUERU TO HAO VIA MAROKAU AND RAVAHERE.						
		° ′	° ′	°	°			
131	Oct. 28	17 47	142 29	79	35.7	1372	Glob. ooze.	Half way between Hikueru and Marokau.
132	" "	18 00	142 29	77	35.6	1620	Glob. ooze.	8 miles west of Marokau.
133	" "	18 05	142 23	78	35.5	742	Pteropod ooze.	About 2 miles off north end of Marokau.
134	" "	18 06	142 24	79	37.6	807	Fine coral sand and manganese nodules.	3 miles off northwest point of Marokau.

Serial Number.	Date. 1899.	Position.		Temperatures.		Depth in Fathoms.	Nature of Bottom.	Remarks.
		Latitude South.	Longitude West.	Surface.	Bottom.			
		° ′	° ′	°	°			
135	Oct. 28	. . .	. . . .	79	48.1	278	Fine coral sand. Manganese nodules. Globigerinae.	Half way between heads of pass between Marokau and Ravahere.
136	" "	18 08	141 49	79	35.2	2187	Fine volcanic mud. Globigerinae.	About 20 miles from last station.
137	Oct. 29	18 07	141 26	78	. .	1713	Globigerinae and few manganese particles.	About 20 miles from last station. Depth indicates rise or spur.
138	" "	18 05	141 03	79	42	425	Coarse coral sand.	About ½ mile off northwest point of Hao.
139	" "	18 08	141 04	79	37.6	812	Coral sand.	2 miles W. of northwest face of Hao.
		HAO TO AKI AKI.						
		° ′	° ′	°	°			
140	Oct. 29	18 27	140 21	77	35.1	2042	Light brown volcanic mud with globigerinae.	20 miles from Hao. Stations 140–144, line Hao to Aki Aki.
141	Oct. 30	18 29	139 53	78	35	1490	Globigerinae. Large species. Few manganese particles.	Ridge 25 miles from last station.
142	" "	18 30	139 30	78	35.1	2103	Fine light brown volcanic mud, with globigerinae.	20 miles from last station.
143	" "	18 34	139 19	78	35.6	1364	Manganese particles. Globigerinae.	5 miles from Aki Aki. 10 miles from last station.
144	" "	18 30	139 15	. .	. .	377	Coarse coral sand, broken shells.	1 mile off southwest end of Aki Aki.
		AKI AKI TO PINAKI VIA NUKUTAVAKE.						
		° ′	° ′	°	°			
145	Oct. 30	18 36	139 14	78	35	1725	Coarse coral sand.	5 miles south of Aki Aki. Stations 145–148, line Aki Aki to Nukutavake.
146	Oct. 31	18 56	139 05	78	35.1	2343	Red clay. Few globigerinae.	20 miles from last station.
147	" "	19 17	138 54	78	35	1688	Manganese nodules. Globigerinae.	6 miles W. of north end of Nukutavake.
148	" "	19 16	139 49	78	38.9	636	Coral sand.	1 mile off north point of Nukutavake.
149	" "	19 23.5	138 46	78	37	860	Nothing in cup. Hard bottom.	3.5 miles northwest of Pinaki, between it and Nukutavake.
		PINAKI TO NUKUTIPIPI.						
		° ′	° ′	°	°			
150	Oct. 31	19 27.5	138 44	79	41	486	Coarse coral sand. Pteropod ooze.	1 mile west of Pinaki. St. 150 to 158, line Pinaki to Nukutipipi.
151	" "	19 27	138 47	79	35	1907	Glob. ooze. Volcanic mud.	5 miles W. S.W. from Pinaki.
152	" "	19 35	139 13	78	35.1	2335	Red clay. Few globigerinae.	25 miles from last station.
153	Nov. 1	19 45.5	139 54	77	35.4	1494	Globigerinae, small nodules and particles of manganese.	40 miles from last station. This ridge may be a spur of Ahunui, or an independent ridge.

Serial Number.	Date. 1899.	Position. Latitude South.	Position. Longitude West.	Temperatures. Surface.	Temperatures. Bottom.	Depth in Fathoms.	Nature of Bottom.	Remarks.
		° ′	° ′	°	°			
154	Nov. 1	19 52	140 16	77	35	2284	Red clay.	20 miles from last station.
155	" "	20 07	141 00	78	35	2391	Manganese particles. Red clay.	40 miles from last station.
156	Nov. 2	20 31	142 00	77	35	2467	Red clay. No organic remains.	60 miles from last station.
157	" "	20 46.5	142 51	78	35	2315	Red clay and number of globigerinae.	About 5 miles southeast from Nukutipipi.
158	" "	20 43	143 0.5	77	39	649	Coral sand. Broken shells. Pteropods.	About 1 mile southeast of Nukutipipi.
							NUKUTIPIPI TO HEREHERETUE VIA ANU ANURUNGA AND ANU ANURARO.	
		° ′	° ′	°	°			
159	Nov. 2	20 42	143 03	77	. .	736	Coral sand, pteropods, broken shells, manganese particles.	1 mile W.N.W. on course of Nukutipipi to Anu Anurunga.
160	" "	20 40	143 09	78	35.5	1609	Coral sand. Few globigerinae. Manganese particles.	Half way to Anu Anurunga. Sounding indicates a low ridge connecting the islands of the Gloucester group.
161	" "	20 37	143 15	78	39	574	Pteropod ooze. Coarse coral sand and manganese particles.	1 mile off east side of Anu Anurunga.
162	" "	20 37	143 18	78	38.5	659	Coral sand, pteropods, and broken shells.	One mile northwest of Anu Anurunga, on line to Anu Anuraro.
163	" "	20 34	143 23	78	35.2	1890	Light gray glob. ooze. Small and large globigerinae.	Half way to Anu Anuraro from Anu Anurunga.
164	" "	20 29	143 29	78	40.7	438	Coral sand.	$\frac{3}{4}$ of mile from shore off southeast side of Anu Anuraro.
165	" "	20 27	143 32	77	42.5	406	Coral sand. Pteropods. Small manganese nodules.	$\frac{1}{2}$ mile northwest of Anu Anuraro. St. 165 to 168, line Anu Anuraro to Hereheretue.
166	" "	20 15	144 00	77	34.8	2265	Red clay. Globigerinae. Manganese.	26 miles from last station.
167	Nov. 3	20 02	144 28	78	34.9	2524	Very soft red clay. Few globigerinae.	3 miles from last station. Continue to find manganese particles and small nodules at nearly every sounding.
168	" "	19 54	144 48	77	35	1719	Globigerina ooze.	6 miles from last station. East of Hereheretue.
169	" "	19 54	144 53	78	39.5	594	Coarse coral sand.	1 mile off the east coast of Hereheretue.
							HEREHERETUE TO TAHITI VIA MEHETIA.	
		° ′	° ′	°	°			
170	Nov. 3	19 54	144 59	78	62.1	189	Coral sand. Manganese particles.	$\frac{3}{10}$ mile from edge of reef on west side of Hereheretue. St. 170 to 176, line Hereheretue to Mehetia.
171	" "	19 50	145 03	78	35.3	1688	Light gray glob. ooze. Manganese particles.	5.3 miles northwest of Hereheretue.
172	" "	19 22	145 47	77	35	2322	Red clay with globigerinae.	50 miles from last station.

Serial Number.	Date. 1899.	Position.		Temperatures.		Depth in Fathoms.	Nature of Bottom.	Remarks.
		Latitude South.	Longitude West	Surface.	Bottom.			
		° ′	° ′	°	°			
173	Nov. 4	18 55	146 32	78	34.8	2440	Red clay. Large haul of trawl of manganese nodules.	50 miles from last, half way to Mehetia from Hereheretue.
174	" "	18 28	147 11	79	35	2087	Two spherical manganese nodules, about 15 mm. in diameter jammed cup open.	
175	Nov. 5	18 03	147 48	78	34.8	2129	Coarse volcanic mud.	14 miles southeast of Mehetia.
176	" "	17 54	148 00	80	38.1	832	Volcanic mud and coral sand.	1¼ miles off southeast face of Mehetia.
177	" "	17 51	148 03	80	69	142	Volcanic rock and coral sand.	⅓ mile off north shore of Mehetia. St. 177–179 Mehetia to Tahiti.
178	" "	17 46	148 23	81	34.9	2111	Volcanic sand.	23 miles from Mehetia.
179	" "	17 35	148 48	80	35	1755	Volcanic sand.	30 miles from Tahiti.
SOCIETY ISLANDS TO TONGATABU, TONGA ARCHIPELAGO VIA LEEWARD SOCIETY ISLANDS, THE COOK GROUP, AND NIUE ISLAND.								
From Tahiti to Leeward Society Islands.								
180	Nov. 15	° ′ 17 30	° ′ 149 41	° 79	° 36.7	981	Volcanic sand. Pteropod ooze.	About halfway to Murea from Papeete. 5 miles from the northeast point of Murea.
From Aitutaki to Niue.								
181	Nov. 22	° ′ 18 54	° ′ 162 31	° 79	° 34.7	2498	No sample.	Sts. 181–184 referred to H. O. Chart No. 825[a], corrected to April, 1896.
182	Nov. 23	18 59	164 47	82	33.4	2882	Red clay. Glob.	. . . . .
183	Nov. 24	19 04	167 41	80	33.9	2472	Red clay. Radiol.	. . . . .
From Niue to Eua (Tonga).								
184	Nov. 26	° ′ 20 15	° ′ 172 00	° 80	° 34	3141	Red clay. Radiol.	. . . . .
185	Nov. 27	21 18	173 31	. .	. .	4173	Light brown volcanic mud. Radiol.	Near 4762 fms. hole, siliceous sponges in trawl. Deepest haul of trawl yet made. Lost thermo.
186	" "	21 18	173 51	77	34.15	4540	Light brown volcanic mud. Radiol.	. . . . .
VAVAU TO FIJI.								
187	Dec. 4	° ′ 18 47	° ′ 174 15	° 79	° . .	682	Pteropods and very peculiar coral sand, resembles volcanic sand, with white crystals of calcite, gray brown.	Between Vavau and Letté. Sts. 185 to 188 referred to B. A. Chart No. 2421, corrected to August, 1899.
188	Dec. 6	18 43	175 28	79	36.2	1381	Volcanic mud, glob.	Beyond Letté to westward.

Serial Number.	Date. 1899–1900.	Position.		Temperatures.		Depth in Fathoms.	Nature of Bottom.	Remarks.
		Latitude South.	Longitude West.	Surface.	Bottom.			
				In Fiji Archipelago.				
189	Dec. 7	° ′ 18 50	° ′ 178 28	° 79	° 42.9	453	Fine coral sand. Pteropod ooze. Few glob.	About in centre of passage between Yangasá–Mothe. Southern extension of eastern Fiji plateau.
190	" "	18 54	178 35	79	47	324	Coral sand. Colored in part by manganese.	Between Namuka and Yangasá. Sts. 189–193 referred to B. A. Chart No. 2691, corrected to Dec., 1897.
191	" "	18 56	178 43	79	39.3	600	Pteropod ooze. Fragments of pumice. Fine coral sand, glob.	6 miles S. 23° W. from west end of Namuka. Between Namuka and Marambo.
192	" "	18 56	178 50	79	42.4	450	Coral sand. Pteropods. Manganese, glob.	2.7 miles N. 19° W. from Marambo. In centre of triangle Marambo, Kambara, Wangava, about 5 miles distant.
193	Dec. 9	18 56.5	179 16	80	37	990	Very fine light yellow brown coral ooze.	About 15 miles west of Kambara, on way to Totoya.
				Fiji through Ellice and Gilbert Islands to Jaluit Marshall Archipelago.				
194	Dec. 21	° ′ 12 43	° ′ 179 50	° 85	° 35.6	1445	Light yellow brown glob. ooze.	H. O. Chart No. 825ª, cor. April, 1895.
			Longitude East.					
195	Dec. 22	10 47	179 30	. .	. .	245	Coral sand, rocky.	Tanner machine. ½ mile south, off Nurakita. B. A. Chart No. 1830, corr. March, 1898.
	1900.							
196	Jan. 1	0 18	173 54	. .	. .	170	Hard bottom.	¾ mile south of village off south side of Apamama. Sts. 196–207 H. O. Chart No. 119, corr. May, 1899.
		Latitude North.						
197	Jan. 2	0 30	173 35	83	35	2221	Light yellowgrayglob ooze. Struck globigerinae of Equat. Current (obtained before in Paumotus)	On way Apamama–Maiana. About 16 miles from northwest end of Apamama.
198	" "	0 46	173 09	84	35.6	1365	Yellow gray glob. ooze. Very coarse large species.	About 9 miles southeast of Maiana.
199	" "	1 12	173 05	84	43.5	413	Same coarse large glob. ooze as before	Halfway to Tarawa from Maiana. Unknown summit.
200	" "	1 20	173 03	. .	. .	95	Broken shells. Coral sand.	About ½ mile from centre of south shore of Tarawa. Tanner sounding machine.
201	" "	1 20	173 04	. .	. .	200	. . . . .	About 1 mile E. of last station, off south shore of Tarawa. Tanner sounding machine.
202	Jan. 3	1 17	173 09	84	35.3	1569	Coarse large globigerinae. Same as before.	About 5 miles S. 12° E. of southeast point of Tarawa. Shoal said to extend there. Evidently no plateau; may be a ridge, connecting the islands Maiana, Tarawa, and Apaiang.

Serial Number.	Date. 1900.	Position.		Temperatures.		Depth in Fathoms.	Nature of Bottom.	Remarks.
		Latitude North.	Longitude East.	Surface.	Bottom.			
		° ′	° ′	°	°			
203	Jan. 4	1 40.5	172 59.5	. .	. .	170	. . . . .	About 2 miles from southeast point of Apaiang, between Apaiang and north point of Tarawa. Tanner sounding machine.
204	Jan. 4	1 52	173 15	84	34.9	2156	Light gray glob. ooze. Small species.	15 miles from Apaiang, on way to southeast point of Maraki, about half way.
205	" "	2 04	173 16	86	. .	431	Coral sand and globigerinae.	About ½ mile off shore off west coast of Maraki, N.W.-by-W. from monument.
206	Jan. 5	2 27	173 09	80	34.8	2255	Glob. ooze.	About 26 miles N.W.-by-N. of Maraki.
207	" "	2 49	173 01	83	35.3	1461	Glob. ooze. Large species.	About 16 miles southeast from centre of south shore of Taritari.
		From Taritari to Jaluit.						
		° ′	° ′	°	°			
208	Jan. 7	3 57	172 00	83	34.7	2486	Light yellow glob. ooze, coarse and fine.	About 60 miles northwest from Taritari. St. 208–239 B. A. Chart No. 983, April, 1891.
209	Jan. 8	4 25	171 13	83	34.7	2505	Light gray glob. ooze, medium size.	About 130 miles northwest from Taritari, about half way to Jaluit.
210	" "	4 54	170 21	83	34.7	2444	Light gray glob. ooze, coarse and medium size.	About 60 miles southeast from Jaluit.
211	Jan. 9	5 20	169 43	83	34.8	2411	Light yellow drab glob. ooze.	About 30 miles from Jaluit.
212	" "	5 44	169 45	82	35	1937	Light gray glob. ooze.	About 5 miles S. ¼ W. from the south point of Jaluit.
		Through the Marshall Archipelago.						
		° ′	° ′	°	°			
213	Jan. 14	6 34	169 13	83	35	2613	Glob. ooze.	About 30 miles northwest from Jaluit.
214	Jan. 15	7 00	169 01	82	35	2137	Coarse globigerinae.	. . . . .
215	" "	7 08	168 56	82	35.9	1283	Coarse globigerinae.	About 9 miles S. 30° E. of southeast point of Ailinglab Lab.
216	" "	7 29	168 32	82	36.5	1068	Coral sand.	6 miles northwest of west point Ailinglab Lab.
217	" "	7 37	168 27	82	37	906	Coarse globigerinae.	Half way to Namu.
218	" "	7 45	168 21	83	39.7	631	Coarse coral sand.	About 2 miles south of south point of Namu.
219	Jan. 15	8 02	167 43	82	35	2179	Glob. mud.	About 12 miles west of centre of Namu.
220	Jan. 16	8 38	167 37	82	35	1897	Glob. mud.	About 12 miles southwest of west point of Kwajalong Island.
221	Jan. 18	11 09	166 46	80	43.4	400	Coral sand.	½ mile south of Southeast pass of Rongelab.
222	" "	11 07.5	166 46	80	39	827	Coral sand.	1½ miles south of Southeast pass of Rongelab.
223	" "	10 49	167 15	80	35	2469	Glob. and light brown volcanic mud. Red clay (?).	About 35 miles southeast from Southeast pass of Rongelab.
224	Jan. 19	10 30	167 42	80	35	2586	Globigerinae and light brown volcanic mud. Red clay (?)	About 35 miles from last station, towards Likieb.

Serial Number.	Date. 1900.	Position. Latitude North.	Position. Longitude East.	Temperatures. Surface.	Temperatures. Bottom.	Depth in Fathoms.	Nature of Bottom.	Remarks.
		° ′	° ′	°	°			
225	Jan. 19	10 15	168 06	81	34.9	2609	Globigerinae and light brown volcanic mud. Red clay (?)	About 35 miles from last station, on way to Likieb.
226	Jan. 20	9 55	168 56	80	34.9	2231	Glob. mud.	About 8 miles W. S.W. of Kapenor Island. West of north point of Likieb.
227	Jan. 21	9 48	169 14	81	42.6	468	Coarse coral sand.	½ mile south of South pass of Likieb.
228	" "	9 47	169 14	81	36.9	934	Coarse coral sand.	1½ mile south of South pass of Likieb.
229	" "	9 40	169 32	81	35.5	1583	Globigerinae. Very fine species.	About half way Likieb to Wotje.
230	Jan. 23	9 19	170 10	81	41.7	482	Coral sand.	1 mile south of Schischmarev Pass.
231	" "	9 17	170 11	81	36.1	1187	Coarse coral sand. Trace of manganese.	2 miles south of last station.
232	" "	8 50	170 26	81	34.9	2221	Wh. and gray glob. ooze.	About 40 miles south of last station, half way between south end of Erikub and Maloelab.
233	Jan. 24	7 54	170 56	80	36.5	1009	Coarse globigerinae.	. . . . .
234	" "	7 21	171 35	81	36	1326	Coarse globigerinae.	About 7 miles N. 50° W. from northwest point of Arhno.
235	Jan. 28	6 57	171 34	82	36	1253	Cream colored coarse globigerinae.	About 6 miles southwest of south point of Arhno.
236	" "	6 34	170 59	81	34.9	2482	Globigerinae.	About 40 miles from last station.
237	" 29	6 11	170 25	81	34.7	2486	Fine glob. mud.	About 40 miles from last station. The same deep water we found on coming north from the Gilberts, and also all through the Marshalls and between the islands both of the Ralick and Ratack chain.

MARSHALL ISLANDS THROUGH THE CAROLINES TO GUAM, LADRONES ISLANDS, AND TO YOKOHAMA, JAPAN.

		° ′	° ′	°	°			
238	Feb. 5	5 48	169 01	82	35	2424	Glob. mud. Coarse diat. cysts.	30 miles west of Jaluit.

Through the Carolines.

		° ′	° ′	°	°			
239	Feb. 9	. . .	. . . .	82	43.5	371	Volcanic and coral sand.	¾ mile south of Port Lottin, Kusaie.
240	Feb. 13	6 49	156 36	82	34.9	2475	Glob. and light brown volcanic mud.	⅓ way Ponapi and Truk. Sts. 240–244 H. O. Chart No. 1754, 1898.
241	" "	6 51	154 39	81	35	2533	Glob. mud. Light brown fine volcanic mud.	⅔ way Ponapi — Truk.
242	Feb. 14	6 55	152 40	82	41.5	526	Coarse coral sand.	About ½ mile south of Nama.
243	Feb. 15	6 47	152 11	82	35	2162	Light gray glob. mud and few volcanic particles.	About 17 miles southeast of South Island, Royalist Islands.
244	Feb. 17	8 06	151 08	81	35	2205	Glob. mud.	About half way between Truk and Namonuito.

Serial Number.	Date. 1900.	Position.		Temperatures.		Depth in Fathoms.	Nature of Bottom.	Remarks.
		Latitude North.	Longitude East.	Surface.	Bottom.			
		NAMONUITO TO GUAM.						
		° ′	° ′	°	°			
245	Feb. 18	9 31	149 36	81	35	2735	Red clay.	50 miles northwest from Magur islet.
246	Feb. 19	10 34	148 25	81	35	2993	Red clay and small particles of manganese nodules.	100 miles further towards Guam. Sts. 245–249 H. O. Chart No. 529, corr. June, 1896.
247	Feb. 20	11 35	147 15	80	35	3213	Manganese nodules. Pumice. Red clay.	100 miles further, same course, towards Guam.
248	" "	12 51	145 46	81	35.8	4813	Manganese. Pumice. Volcanic particles. disks of diatoms(?).	Our deepest sounding. 100 miles further, same course, towards Guam. Thermometer could not have registered correctly.
249	Feb. 21	13 08	145 25	80	35	2337	Fine volcanic sand.	About 25 miles further, same course, distant 45 m. from north end of Guam.

NOTES ON THE DEEP-SEA HAULS OF THE TRAWL AND DREDGE MADE BY THE "ALBATROSS" AND THE "CHALLENGER" IN THE PACIFIC.

The "Challenger" made four hauls of the trawl or dredge from the Admiralty Islands to Japan, eight between Yokohama and the Hawaiian Islands, four between the Hawaiian Islands and Tahiti, and eleven between Tahiti and Valparaiso. The "Albatross" made thirteen hauls in the line San Francisco to Tahiti across the deep Moser Basin.

In other parts of the Pacific exclusive of the Southern Ocean we have only the deep-water trawling of the "Challenger" near Fiji and Tongatábu and thence to New Zealand and south from Valparaiso; exclusive of hauls made in the enclosed seas to the westward of Borneo and New Guinea, the number of hauls in the deep areas of the Pacific are few in number, and have thus far made us acquainted with a comparatively small number of deep-water types. The few hauls made by the "Albatross" in the insular area of the Pacific would seem to indicate that in the Paumotus, Society Islands, Tongas, Ellice, Gilbert, and Marshall Islands the fauna of these areas was extremely poor as compared with the wealth of animal life brought to light by the "Blake" in the West Indies and by the "Albatross" in the Panamic district near the Galapagos and off the coast of Central America. The only other hauls in the Pacific are the few made by the "Gazelle" near the Fiji in less than 800 fathoms, and the large collections made for many years by the "Albatross" along the shore of Oregon, Washington, and Alaska, the Aleutian Islands, and in the Bering Sea. It must be remembered, however, that these collections of the "Albatross" were all obtained at a comparatively short distance from the American continent, — the greatest number of deep-sea hauls made at a distance from a continental area being those of the "Albatross" Expedition of 1891 in the Panamic district, a number of which were from five to 700 miles from the continental slope of Central America.

It is interesting to compare the lines run across the Pacific by the "Challenger" with those explored by the "Albatross" in the present expedition. The line run by the "Albatross" from San Francisco to Tahiti starts in lat.

31° 10′ N., long. 125° W., and terminates at Tahiti off Pt. Venus about in lat. 17° 30′ S., and long., 149° 30′ W. That of the "Challenger" starting north of the Hawaiian Islands in lat. 38° 9′ N., and long. 156° 25′ W., and ending also at Tahiti, converges towards the line of the "Albatross," so that we have an excellent opportunity of comparing the collections of the "Challenger" in the central Pacific with those obtained by the "Albatross" from the great red-clay and manganese-nodule area of the Pacific Ocean to the eastward. An examination of the results as recorded by Sir John Murray,[1] and those which I here give from the trawling of the "Albatross" show plainly that at great depths and far from continental areas or insular plateaux the bottom fauna of the great depths is comparatively poor except when the trawling is made in the line of the great equatorial currents, where the bottom fauna receives a larger amount of food, derived from the dead remains of the pelagic fauna falling to the bottom.

A similar increase in the number of animals brought up in the trawl can also be noted in the hauls made by the "Challenger" on the line east of Japan, while practically in the track of the great Japanese current sweeping to the eastward. In marked contrasts to this line and to the results obtained in the track of the equatorial current by the "Albatross" are the scanty hauls obtained by the "Challenger" from the Admiralty Islands north to Japan.

The line of dredgings made from Tahiti to Valparaiso is also relatively richer than the two principal lines across the deepest parts of the central Pacific explored by the "Challenger" and "Albatross." That is in part due to the nature of the bottom, which is often made up of Globigerina ooze, and also undoubtedly to the fact that the eastern extension of the "Challenger" line from Tahiti was run in the northern extension of the basin of the Southern Ocean, which, as is well known, has supplied a far richer deep-water bottom fauna than that found in the intertropical areas of the Pacific.

To facilitate the comparison between the results obtained in the Pacific by the "Challenger" and those of the "Albatross" during her trip to the

[1] In the General Summary of the "Challenger" results, and in the Deep Sea Deposits ("Challenger" Expedition) by Murray and Renard.

tropical Pacific, I have prepared an abstract of the results of the "Challenger" from trawling and dredging,[1] as well as a succinct account of the surface tows and of the bottom deposits compiled from the published records of the "Challenger." The same has been done for the results of the "Albatross," which have been treated in the same way and discussed with reference to the Pacific area covered by us to the eastward and northward of the "Challenger" lines, and to the westward of the Society Islands as far as Fiji, and from there to Guam via the Ellice, Gilbert, Marshall, and Caroline Islands. From Guam, as our line to Yokohama practically duplicated that of the "Challenger" we merely made a passage from the Ladrones to Japan.

The following are the results of the trawling and dredging of the "Challenger" in the Pacific, from the Admiralty Islands to Yokohama, thence to the Hawaiian Islands, to Tahiti and Valparaiso.

Leaving out of consideration Station 220, not more than eighty miles from the Admiralty Islands, where a good haul of the trawl was made in 1100 fathoms, we have Stations 221 and 222, where no haul was made; we then come to Station 223, lat. 5° 31′ N., long. 145° 13′ E., where a haul of the trawl was made in 2325 fathoms, but which contained only a young Hyocrinus, a small siliceous sponge attached to a piece of pumice, and a Penæid and a couple of Gonostoma, neither of which probably came from the bottom. This station was 464 miles from Guam, and some of the Carolines were not more than 90 miles distant. At the next station, 224, lat. 7° 45′ N., long. 144° 20′ E., in 1850 fathoms, the nearest Caroline being 52 miles and Guam 330 miles, the trawl contained only a deep-sea coral, one species of starfish, and two Ophiurans. At the deepest station, 225, lat. 11° 24′ N., long. 143° 16′ E., occupied by the "Challenger" in 4475 fathoms, about 140 miles southwest of Guam, only samples of the bottom were brought up while sounding. At the next station, 226, lat. 14° 44′ N., long. 142° 13′ E., in 2300 fathoms, about 150 miles northwest from Guam, the trawl brought up fragments of Freyella, and one

[1] General Summary of the scientific observations and results at each of the "Challenger" observing stations, by John Murray.

specimen of Gonostoma. The trawl was again used at Station 230, lat. 26° 29′ N., long. 137° 57′ E., in 2425 fathoms, about 250 miles west of the Bonin Islands, 510 miles from the Liu Kiu Islands, and about 480 miles from the nearest point of the coast of Japan. It was only when off Japan in 345 fathoms, near the noted Hyalonema ground, and other stations near the coast (Stations 232–233, 235–237), that rich hauls of the trawl were again made.

On the line east of Japan, at a distance of about 975 miles from the coast, Honolulu being distant 2484 miles, a good haul of the trawl was made in 2300 fathoms, Station 241, lat. 35° 41′ N., long. 157° 42′ E. An excellent haul was also made at Station 244, lat. 35° 22′ N., long. 169° 53′ E., in 2900 fathoms, Honolulu distant 1891 miles, and the nearest of the Kurile and Aleutian Islands about 1250 miles. A good haul was obtained at Station 246, lat. 36° 10′ N., long. 178° E., in 2500 fathoms, about 120 miles east of Station 244, while at Station 248, lat. 37° 41′ N., long. 177° 04′ W., in 2900 fathoms, comparatively little was obtained: two siliceous sponges, a specimen of Monocaulus and a Tunicate, with fragments of a Holothurian and an Echinid. A still poorer haul was made in 2740 fathoms at Station 252, lat. 37° 52′ N., long. 160° 17′ W., Honolulu distant 1002 miles.

At Station 253, lat. 38° 09′ N., long. 156° 25′ W., 3125 fathoms, a few Annelids and Polyzoa were collected. Nothing came up except a manganese nodule from the next station in 3025 fathoms, Honolulu distant 852 miles. When 568 miles from Honolulu, in 2950 fathoms, Station 256, lat. 30° 22′ N., long. 154° 56′ W., a Leda and a deep-sea sponge came up with manganese nodules. The rich hauls of two of the stations, 244, 246, in deep water at a great distance from land, about 1200 miles from the nearest land, but in the extension of the Japanese current, are in marked contrast with the poverty-stricken hauls which characterized the trawling in the line of Admiralty Islands to Japan.

On the line Hawaiian Islands to Tahiti, at Station 264, lat. 14° 19′ N., long. 152° 37′ W., in a depth of 3000 fathoms, Tahiti distant 1920 miles and Hawaii about 300 miles, only one specimen of Cladorhiza was obtained and fragments of a Euplectella. One hundred miles further south, at

Station 265, lat. 12° 42′ N., long. 152° 01′ W., in 2900 fathoms, obtained only one specimen of Gonostoma. At Station 270, lat. 2° 34′ N., long. 149° 09′ W., two species of deep-sea Keratosa were obtained in 2925 fathoms, Tahiti distant about 1200 miles. At Station 271, lat. 0° 33′ S., long. 151° 34′ W., about half-way between Hawaii and Tahiti, in 2425 fathoms, nine species of Keratosa, six of Hexactinellidæ, and, in all, twenty-nine species of Invertebrates and Fishes exclusive of Protozoa. At the next station, 272, lat. 3° 48′ S., long. 152° 56′ W., in 2600 fathoms, sixteen species of Invertebrates and Fishes were collected. At Station 274, lat. 7° 25′ S., long. 152° 15′ W., Tahiti and the Marquesas about equidistant, 625 miles, Caroline Island 202, and Vostok Island 160 miles. At Station 276, lat. 13° 28′ S., long. 149° 30′ W., in 2350 fathoms, Tahiti distant 240 miles, only six species (10 specimens) of Invertebrates and Fishes are recorded from the trawl, while the hauls off Tahiti, though poor, contained again a comparatively large number of specimens and species.

On the line from Tahiti to Valparaiso the hauls at Station 280, 1940 fathoms, and at Station 281, 2385 fathoms, distant from Tahiti less than 200 miles south, again showed a very great diminution in the number of specimens and species collected in the trawl. A similar condition exists at Stations 285, lat. 32° 30′ S., long. 137° 43′ W., and 286, in depths of 2375 and 2335 fathoms, about 1300 miles southeast from Tahiti and nearly 600 miles south of the islands of the southeast extremity of the Paumotus. The fauna at Station 289, lat. 39° 41′ S., long. 131° 23′ W., about 250 miles southeast of Station 285, in 2550 fathoms, was equally poor.

From Station 289 the "Challenger" ran a line nearly east towards Valparaiso, distant 2907 miles. At Station 291, lat. 39° 13′ S., long. 118° 49′ W., in 2250 fathoms, only two species of Monaxonida were obtained. At Station 293, lat. 39° 04′ S., long. 105° 05′ W., in 2025 fathoms, an Actinarian and fragments of siliceous sponges and Gorgonians and Polyzoa were obtained attached to manganese nodules; Valparaiso distant 1661 miles. One specimen of Holopsamma was obtained at Station 294, lat. 39° 22′ S., long. 98° 46′ W., in 2270 fathoms, Valparaiso distant 1368 miles. At Station 295, lat. 38° 07′ S., long. 94° 04′ W., one fish (Cyema) was collected in the trawl, which is also, like Gonostoma, probably a fish belonging to

the pelagic types, and a Leptocephalid form of Nemichthys. At Station 296, lat. 38° 06′ S., long. 88° 02′ W., about 500 miles from Juan Fernandez, seventeen species (twenty specimens) of Invertebrates were obtained in 1825 fathoms, Globigerina ooze, and at the next station, 297, lat. 37° 29′ S., 302 miles from Juan Fernandez, only a single specimen of Thenea is recorded; while at Station 298, lat. 34° 7′ S., 122 miles from Valparaiso, nearly 100 specimens of Invertebrates were obtained, belonging to thirty-three species, and the hauls from Valparaiso south to the Gulf of Peñas, in 1325 to 2160 fathoms, at no time more than 450 miles from shore, in blue mud or Globigerina ooze, were also rich in specimens and in species, compared with hauls taken in deep water and far from continental slopes or large archipelagos.

The following are the results of the trawling of the "Albatross" during her present cruise in the tropical Pacific.

MANGANESE NODULES FROM STATION 2.

At Station 2, 2368 fathoms, lat. 28° 23′ N., long. 126° 57′ W., the trawl came up with the bag full of red clay and of manganese nodules, siliceous sponge spicules, a large pink Benthœcetes, spines of Phormosoma, Euphronides, and Benthodytes in fragments. Together with the manganese nodules came up many sharks' teeth, whale ear-bones and other fragments

of cetaceans more or less coated with manganese. There were a number of species of sharks represented : Charchaordon, Lamna, Oxyrhina, Carcharias. There were also a number of flat slabs coated with manganese, the majority from three to four inches thick, but many were nearly six inches through. We must have brought up at least 800 pounds' weight of nodules. The slabs seemed to be composed of volcanic ash. There were many rounded masses of pumice covered by manganese and fragments of the stem of a Gorgonian (Isis) coated with manganese.

At this Station we obtained 116 sharks' teeth, a few ear-bones and other bones of whales and dolphins.

NOTE. — Sir John Murray informs me that at Station 2 some of the material which seemed to be manganese nodules proved to be rocks, evidently of continental origin, covered with a thin coating of manganese.

Mr. J. J. H. Teall, of the Geological Survey of England, who examined these rocks, reports that they are a fragment of a rounded pebble, consisting of a typical hornblende andesite; a subangular fragment of a pale-green serpentine; an angular fragment of a fine-grained sandstone composed of grains of quartz, felspar, and epidote, minute grains of mica being also present; fragments of a well-rounded pebble of black chert, traversed by microscopic quartz veins.

How these pebbles, having all the characteristics of glacial-worn pebbles, came to be carried to this point is an interesting question. As the shark's-teeth and cetacean bones found in the red clay seem to indicate that since tertiary times there have been but very insignificant deposits at great distance from continental areas, similarly we may be tempted to assume that these pebbles, which could not have been transported to their present locality by any agency of the present epoch, were carried to it during the glacial epoch, the thin coating of manganese indicating how small have been the bottom deposits since the glacial period.

The "Challenger" obtained two bushels of manganese nodules at Station 281, south of Tahiti, lat. 22° 21′ S., long. 150° 17′ W., in 2385 fathoms, with centres of volcanic tufa and larger slabs covered at the surface and in the cracks. The rounded masses of pumice probably have been carried out to sea for a long distance and finally sinking became coated with manganese on falling in the red clay deposit. This locality of the "Challenger" is only about 300 miles from our Station 173, where we also obtained a magnificent haul of red clay and manganese nodules and sharks' teeth.

From south of Tahiti on the way to Valparaiso the "Challenger" also obtained manganese nodules at Stations 285, 286, 289, in 2375, 2335, and 2550 fathoms; and further to the east, at Stations 293 and 297, in 2025 and 1775 fathoms. The "Challenger" also found manganese nodules in 2160 fathoms, about 100 miles from the coast of South America, as well as in the Atlantic far from continental land, and at one station in the Indian Ocean in 2600 fathoms; but the "Challenger" obtained none north of the Equator, either in the Atlantic or in the Pacific, so that this first haul of ours in lat. 28° 23′ N. and long. 126° 57′ W., as well as hauls further south on our way to the Marquesas, greatly extend the area over which such deposits of manganese nodules and red clay probably exist, — areas which, according to Murray, are situated in deep water and far from continental land, too far from land to be masked by telluric deposits, and at too great a depth to be covered by the shells of Foraminifera and other pelagic animals, as suggested by Murray. The "Valdivia" obtained manganese nodules in the Southern Atlantic in lat. 30° 34.9′ S., long. 6° 10.2′ W., about 2600 fathoms.

We could find no spherules of cosmic iron in the few samples of manganese nodules which we ground to powder.

In the track of great oceanic currents Globigerinæ shells extend to greater depths, and their tests are found mixed with red clay quite frequently at depths quite beyond those at which they ordinarily disappear; see Stations 14 to 22, on our way to the Marquesas, where the deposit is a Globigerina ooze at depths far beyond those at which, according to Murray, Globigerina ooze should occur, — in depths of 2776, 2440, 2463, 2495, and 2287 fathoms.

At Station 10, in 3088 fathoms, lat. 16° 38′ N., long. 136° 14′ W., we lowered the "Blake" trawl. Unfortunately there was no evidence of the trawl having been on the bottom, although we had as much wire-rope out in proportion to the depth as in other hauls. The net came up clean, and although it towed open through such an immense length of column of water, the net contained nothing which we had not caught with the tow-net inside of 200 fathoms from the surface. It had so-called deep-sea fishes, — Cyclothone and Myctophum, — and deep-

sea Crustacea, which are obtained in the open tow-nets at less than 150 fathoms from the surface.

At Station 13, in 2690 fathoms, lat. 9° 57′ N., long. 137° 47′ W., red clay, Radiolarian ooze, light-brown ooze. The "Blake" trawl came up full of large manganese nodules, balls varying in diameter from $4\frac{1}{2}$ to over 6 inches; a few of the largest measured $6\frac{1}{4}''$ in diameter. The bottom contained some animal life, but of course in their long passage to the surface, among such a mass of rubble, the delicate deep-sea animals come up very much disfigured and ground to pieces. Attached to some of the nodules we found pink Webbinas, a small Voluta (?), three species of Holothurians, among which one brilliant red I could recognize as a Peniagone. We found also a fragment of a stem of Bathycrinus, half a dozen joints or so, and part of the upper portion of a Metacrinus (?), a small Brachiopod (Magasella ?) and a few worm-tubes, large siliceous spicules, and a species of incrusting siliceous sponge, together with delicate calcareous worm-tubes attached to some of the flat nodules, and some Serpulæ tubes. A few Schizopods found their way into the trawl-net on its way to the surface. There were also large reddish-brown Globigerinæ, evidently living at that depth in the interstices of the manganese nodules,[1] a large red Nemertean allied to Pelagonemertes, and a small tough-skinned gray-white Actinian measuring about an inch in diameter when contracted. We also brought up the same egg-shaped organism with a thin greenish skin about half an inch in diameter, found by the "Blake" and former "Albatross" expeditions, the nature of which I have not been able to determine. The manganese nodules were all more or less mammary; this is specially well-developed in the flat pieces.

Station 17, 2463 fathoms, lat. 0° 50′ N., long. 137° 54′ W., fine, light-gray, yellowish Globigerina ooze. An excellent haul was made with the "Blake" trawl, considering its depth and its distance from the nearest land;

[1] Dr. Mayer kept surface Globigerinæ in the dark for three weeks. They were brilliant carmine when collected, and at the end of that time had lost all their color and had become quite pale, like those found at the bottom. The only colored Globigerinæ we found on the bottom were those living attached on the surface or between the cracks of manganese nodules. These were dull reddish-brown, with much heavier and coarser tests than the carmine or colored species living at the surface or near it.

but it being on the line of the equatorial current, it also shows the effect of the increased supply of food carried by a great oceanic current. This haul is a striking contrast to those taken farther south to the southeast of Tahiti at about the same depth, but outside the range of any great current. In that district we found practically nothing living on the red-clay bottom. It seems natural to infer that the lines of migration of the deep-sea fauna of the tropical Pacific must have been along the track of the equatorial current.

The trawl contained three species of Holothurians, one of which was bright carmine; a number of siliceous sponges, among which a small Hyalonema with its Zoanthus attached to the bundle of spicules; a few colossal spicules nearly as thick as a lead pencil; a lot of the Neusina we collected in 1891 in the Panamic region; two species of Actiniæ, one of which a brilliant carmine, the other heavy, thick-skinned, whitish, both found attached to siliceous spicules; a species of Archaster, and a good specimen of Linopneustes; a peculiar fish with a long head and pectoral fins, spread vertically upright across the flanks, and having two long caudal filaments; a few manganese nodules, and a number of small sharks' teeth; a couple of specimens of Scalpellum, and what I took to be fragments of the interesting Ascidian Octacnemus of Moseley. Some of the large siliceous spicules must have been 24″ long. Also a small white, thick, stiff-armed Ophiuran; some worm-tubes built up in part of mud and of siliceous spicules; two excellent specimens of Terebella, a Pectinaria-like worm, and great numbers of Radiolarians collected from the intestines of the Linopneustes; two specimens of Amusium; a Gasteropod; a Webbina attached to Neusina; a small Plumularian; a fragment of a Polyzoan; and a Eucopia which found its way into the net near the surface. The list of the contents of this trawl-haul is quite sufficient, when contrasted to that of the haul at Station 173, to emphasize the contrast between localities in the wake of the great equatorial current and those outside of its influence.

At Station 25 we lowered the beam-trawl in 830 fathoms, lat. 8° 48′ S., long. 139° 48′ W., in the channel between Nukuhiva and Washington Islands, the bottom being Globigerina ooze and volcanic mud. The trawl

tripped, but brought up three specimens of Mopsea and an Astroschema attached to it, of a pinkish-orange color, three Actiniæ (Stephanactis), pink in color, with warty columns, a Pheronema, and pieces of siliceous sponges. A second haul in the same place brought up a couple of small manganese nodules, surface fishes, Sternoptyx, and Cyclothone; a large black Malacosteus, like the Malacosteus indicus of Günther, with long barbels, a large eye, and a comma-shaped, phosphorescent organ, green-yellow at the point; the phosphorescence was quite brilliant when the fish was placed in the dark. The spot was $\frac{5}{6}''$ long, the eye itself was a beautiful dark carmine. The net also contained Atolla Alexandri of Maas, and a specimen of the thick-nosed phosphorescent surface fish, Ganadis, three red deep-water prawns, two specimens of Benthesicymus. The latter we have had from 300 fathoms in the open tow-net.

At Station 31, in 2700 fathoms, lat. 12° 20′ S., long. 144° 15′ W. Red clay. The sea being a little too heavy for a successful haul, the "Blake" trawl came up with the net badly torn; it must have had too heavy a load of manganese nodules, as the part of the bag left contained about a plate full of small, irregularly shaped nodules, incrusting also volcanic rock. The net probably gave away as we broke ground, judging from the indications of the accumulator.

There is a marked contrast between the hauls on this oceanic line (Stations 1–72) and our results in the "Albatross" expedition of 1891, when never more than 700 miles from shore. We always made excellent hauls, and there seemed to be an ample food supply on the bottom of that area, brought by currents and winds from the mainland.

At Station 73 we lowered the trawl in 807 fathoms, lat. 17° 27′ S., long. 149° 32′ W. Fine volcanic sand, Pteropods. It brought up a mass of fine volcanic mud filled with sticks and leaves and decayed vegetation, fragments of rocks and other telluric material, pieces of sugar cane, and fragments of cocoanut shells. In addition, in the midst of this mixture, one Holothurian, a Willemoesia, broken shells, fragments and specimens of Hyalea and many other Pteropod shells, also fragments of Lamellibranchs.

At Station 133 we lowered the trawl in 742 fathoms, lat. 18° 05′ S., long. 142° 23′ W. Pteropod ooze. The trawl came up in pieces; the

pocket of the bag contained a piece of obsidian as large as a hen's egg, a piece of pumice and of coral, both coated with manganese, a few fragments of wood similarly coated, a fragment of Tubipora, also coated, and a mass of Globigerinæ connected by manganese, as well as volcanic fragments and particles of manganese.

At Station 134, in 807 fathoms, lat. 18° 06′ S., long. 142° 24′ W. Fine coral sand and minute manganese nodules and Pteropod ooze. We sent the swabs down; brought up two specimens of Brisinga, a couple of small Diadematidæ, fragments of a Gorgonian stem coated with manganese, a few young siliceous sponges and fragments of others, two species of Ophiurans, and fragments of a Bryozoan. Also some small manganese nodules and sharks' teeth. A poor haul for such a depth and such a bottom.

At Station 139, in 812 fathoms, lat. 18° 08′ S., long. 141° 04′ W. Coral sand. The "Blake" trawl brought up a fine Brisinga, a couple of genera of Gorgonians, a Galathodes, a piece of stem of an Isis, young siliceous sponges, a fine Penæus from intermediate waters (?), and some Ophiurans, — in fact, the same things we brought up at Station 134 in the tangles. The ground must have been very rough, as the trawl caught repeatedly, and when it reached the surface was found badly torn along the sides.

At Station 173, in 2440 fathoms, lat. 18° 55′ S., long. 146° 32′ W. Red clay. The "Blake" trawl brought up about half a ton of flattened manganese nodules, generally mammilated on the surface, and slabs of all sizes, from that of a large potato to that of a pea. Many of the nodules were spherical or ellipsoidal. Many of the flattened pieces contained large sharks' teeth; there were but few ear-bones or other bones of cetaceans. Some of the sharks' teeth were fully 4″ long.

At Station 183, in 2472 fathoms, lat. 19° 04′ S., long. 167° 41′ W. Red clay washed out. Radiolarian ooze, volcanic particles. The "Blake" trawl came up with a large hole on the side and the bottom partly carried away, yet there were still left in the bag a number of small flat manganese nodules, from the size of a small walnut down. The bag also contained a few pieces of pumice and one shark's tooth, a few siliceous sponge-spicules, and fragments of a small siliceous sponge.

At Station 185, in 4173 fathoms, lat. 21° 18′ S., long. 173° 31′ W. Light-brown volcanic mud and Radiolarian ooze. A small "Blake" trawl was lowered, protected by canvas flaps; it came up in excellent condition. A half-gallon jar was filled with fragments of a large siliceous sponge allied to Aulochene or Crateromorpha which the "Challenger" obtained in shallower water, in about 500 fathoms, in the western Pacific.

The bottom deposits collected by the "Albatross."

A comparison of the deposits collected by the "Albatross" on the line from San Francisco to Tahiti with the "Challenger" line of soundings from Station 253 north of the Hawaiian Islands to Tahiti shows a great similarity in their characteristic structure. At Station 2 (lat. 28° 23′ N., long. 126° 51′ W.), in only 2368 fathoms, the "Albatross" struck the characteristic Pacific red clay which was met with as far as Station 14 (lat. 6° 41′ N., long. 137° W.), where in 2776 fathoms Globigerinæ and Foraminifera predominated and no Radiolarians occurred, while at next station, in 2583 fathoms, Radiolarians were again obtained, as well as at Station 18 (lat. 6° 25′ S., long. 138° 59′ W.), in 2468 fathoms, and at Station 23 (lat. 8° 33′ S., long. 139° 36′ W.), in 1802 fathoms, near the Marquesas, together with volcanic particles. At the intermediate stations, varying in depth from 1939 to 2463 fathoms, Globigerina ooze was obtained. It may be stated that Stations 14 to 23 are in a general way in the tract of the equatorial current and counter current, characterized by the larger number of species constituting its surface fauna than in the stations to the north.

Note. — Sir John Murray in his Report on the bottom deposits has frequently called attention to the great bulk of pelagic Foraminifera which are found in the bottom deposits. While it is true that many of the Globigerinæ of which the tests are collected must live at or very near the bottom[1] yet the pelagic species, which are far less numerous, often compose fully 80 per cent of the carbonate of lime occurring in the deposit. According to Brady he records as collected by the "Challenger" only 19 species of pelagic Foraminifera: seven of Globigerinæ, six species of Pulvinulina, and the following genera, Orbulina, Hastigerina, Sphæroidina, Candeina, Cymbalopora and Chilostomella, represented each by one species. But they occur on the surface in such swarms that their dead tests, when they reach the bottom, completely overwhelm those of the bottom living species.

[1] W. B. Carpenter, in Proc. R. S., Vol. XXIII., p. 235.

The same may probably be said of the Radiolarians. The surface Radiolarians are less numerous than the species living near the bottom, but the pelagic species occur in such hosts as to outweigh at certain localities those living on the bottom. The number of pelagic species of Radiolarians[1] is far greater than that of the Globigerinæ, and there are no groups of the former living attached to the bottom, as in the case with the arenaceous and porcellanous types of Foraminifera. On the other hand there must be living and floating in close proximity to the bottom, far from continents and at depths greater than 2000 fathoms, hosts of abyssal Radiolarians, among which the Nasselaria and the Phæodaria predominate. As a general rule the abyssal forms are characterized by their smaller size and massive skeletons, while the surface types are distinguished by their more delicate skeletons.[2] The surface and pelagic Radiolarians probably do not extend far beyond 200 fathoms in depth, and belong especially to the Spumellaria and Acantharia, and, according to Haeckel, with but few Osculosa, and fewer Phæodaria than Nassellaria. Unfortunately, no detailed account of the bathymetrical range of the minor groups of Radiolarians accompanies the report of Haeckel,[3] but he naturally attaches the greatest significance to the dependence of their geographical distribution on oceanic currents.

The bottom deposit at the stations in the vicinity of the Marquesas are characterized by an admixture of Globigerina ooze and volcanic particles. In the channel separating the Marquesas from the northwestern Paumotus, a distance of not more than 450 miles, the deeper parts, in from 2456 fathoms to 2700 fathoms, are marked by all the characteristics of the deposits in the deeper parts of the eastern Pacific north of the Marquesas; the deposits passing from red clay associated with Radiolarians to red clay mixed with Foraminifera, and in the lesser depths, 1208 fathoms to 1932 fathoms, we meet with deposits consisting of Globigerina ooze, and finally coral sand in the vicinity of the Paumotu Plateau.

Again in the channel separating the Paumotus from the Society Islands a deposit allied to red clay, composed in part of Globigerinæ, was found in the deeper parts at a depth of somewhat over 2200 fathoms; the Globigerinæ becoming mixed with large proportions of volcanic mud as we approached the Society Islands.

[1] Haeckel enumerates more than 4300 species, and remarks that probably twice that number could be distinguished from a more detailed examination of the "Challenger" material. Report on the Radiolaria collected by H. M. S. "Challenger," 1887. Zoölogy; Vol. XVIII., First Part, p. ii.

[2] Haeckel, l. c., p. clii.

[3] Haeckel, l. c., p. cxlvi.

Through the Paumotu Archipelago the soundings in less than 1400 fathoms are marked by the frequent occurrence of Pteropod ooze and of Globigerinæ, but by far the greater number of soundings show a bottom made up of Globigerinæ and of coral sand in proportion to the distance from the atolls; the coral sand being coarser nearer the shores, gradually becoming finer as we proceed seaward, and at the same time containing a larger percentage of Globigerinæ or of Pteropod shells. Compare the records of the shallower stations in the northwestern Paumotus, such as Stations 79, 89, 91, 96, 106, 107, 115 to 117, made up of comparatively coarse coral-sand, with deeper stations like 82, 97, 104, 109, at which the coral sand is finer, containing a larger percentage of Pteropods or Globigerinæ, and with the still deeper stations like numbers 77, 87, 93, 94, 102, 103, 110–114, where the Globigerinæ make up the greater part of the deposit.

A similar state of things is found to hold good with the deposits at the stations occupied in the central Paumotus, as well as in the easternmost islands of the Paumotus we visited. When the depths separating the islands are greater, as at Station 146 (lat. 18° 56′ S., long. 139° 05′ W.) and 152 and 154 to 157 (lat. 20° 46.5′ S., long. 142° 51′ W.), on the way from Pinaki to Nukutipipi, we find again red clay in depths varying from 2284 to 2467 fathoms containing a greater or less percentage of Foraminifera. Similarly at Stations 166 and 167 (lat. 20° 02′ S., long. 144° 28′ W.), in the deep water which separates Anu Anuraro from Hereheretue, in 2265 and 2524 fathoms, the bottom deposit is red clay with an admixture of Foraminifera; while at stations varying in depth from about 700 fathoms to nearly 2000 fathoms the deposit is made up of coral sand, Pteropod ooze, and Globigerinæ in different percentages, as in the deposits of the northwestern Paumotus.

The deep soundings between Hereheretue and Tahiti at Stations 172 and 173 (lat. 18° 55′ S., long. 146° 32′ W.) were made up of red clay and Globigerinæ; and on approaching Tahiti the coral sand which characterized the vicinity of the atolls in the Paumotus is replaced in the Society Islands by volcanic mud and volcanic sand and a small percentage of Globigerinæ.

One cannot fail to notice the frequent occurrence of particles of manganese and of small manganese nodules in the deposits through the Paumotus and Society Islands.

In the deep water between Niue and Tonga which culminates at Station 186 (lat. 21° 18′ S., long. 173° 51′ W.) in 4540 fathoms, we meet with red-clay deposits containing Radiolaria, as at Stations 183 (lat. 19° 04′ S. long. 167° 41′ W.), 184, and 185 in 2472, 3141, and 4173 fathoms, though at Station 182 the red clay in 2882 fathoms contained a considerable percentage of Globigerinæ.

On the way from Vavau to Fiji we found volcanic mud to the westward of Letté while crossing the volcanic ridge which runs parallel to the Tonga Islands Plateau. Crossing the eastern Fiji Plateau we meet with deposits of coarse coral-sand, Pteropod ooze, and fine coral-ooze, associated with manganese particles and Globigerinæ, much as in the deposits of the Paumotus.

On our way through the Ellice and Gilbert Islands to Jaluit we obtained in the proximity of the islands coarse coral-sand, Pteropod ooze, and fine coral-sand ooze more or less mixed with Globigerinæ. In the deeper waters separating the islands of each group, and the groups themselves, we encountered only Globigerina ooze, varying greatly in the size of the species obtained; very coarse species being met with at Stations 198, lat. 0° 46′ N., long. 173° 09′ E., and 202 in the Gilbert group in 1365 and 1569 fathoms.

At Station 197, in 2221 fathoms, between Apamama and Maiana, we met with the same Globigerinæ, characterizing the equatorial current, which we had obtained before in the Paumotus and to the northward. Although on our way to Jaluit from Taritari we sounded in over 2500 fathoms, yet we nowhere obtained red clay in the bottom deposit, either on that line or in the deep water separating the islands of the Ellice or of the Gilbert group. See Stations 197, 2221 fathoms; 204 (lat. 1° 52′ N., long. 173° 15′ E.), 2156 fathoms; 206, 2255 fathoms; 208 (lat. 3° 57′ N., long. 172° E.), 2486 fathoms; 209, 2505 fathoms; 210, 2444 fathoms; 211 (lat. 5° 20′ N., long. 169° 43′ E.), 2411 fathoms; at all of which Globigerina ooze was obtained. We found the same conditions in the Marshall group, coarse coral-sand, passing, according to depth and distance from land, into fine

coral-sand, or coral-sand ooze, with a gradually increasing percentage of Globigerinæ. These are met with in as great a depth as 2613 fathoms, at Station 213 between Jaluit and Ailanglab Lab and all through the Marshall group in deep water in the channels between the different groups. See Stations 219, 2179 fathoms; 226, 2231 fathoms; 229, 1583 fathoms; 232, 2221 fathoms; 233–234, varying from 1009 fathoms to 2486 fathoms; while in the shallower stations referred to above, such as Stations 216, 1068 fathoms; 218, 631 fathoms; 221, 400 fathoms; 222, 827 fathoms; 227, 228, 230, in 468, 934, and 482 fathoms, — we find that the bottom deposits contain coral sand, changing from coarse to fine and then to ooze with the increase in depth.

Red clay is, however, met with in the bottom deposits of the northern part of the Marshall group between Rongelab and Likieb at Stations 223–225, in depths varying from 2469 to 2609 fathoms, though even at that depth it is associated with a considerable percentage of Globigerinæ.

Similarly on our way through the Carolines we found Globigerinæ to constitute a considerable percentage of the bottom deposits to depths of nearly 2500 fathoms. See Stations 240, 241, lat. 6° 49′ N., long. 156° 36′ E.; 243, 244, lat. 8° 06′ N., long. 151° 08′ E. The bottom deposits in the Carolines consist, as we would naturally expect from the geological structure of the Carolines, near the island groups, in great part of volcanic mud mixed with coral sand and Globigerinæ; the size of the sand, volcanic or coral, gradually decreasing as the depth increases. See Stations 239 and 242.

It is only as we pass into the "Caroline Deep" separating the Carolines from Guam and the Ladrones that we come upon bottom deposits consisting of red clay, manganese nodules, and pumice, as well as volcanic particles. See Stations 245, 2735 fathoms; 246, lat. 10° 34′ N., long. 148° 25′ E., 2993 fathoms; 247, lat. 11° 35′ N., long. 147° 15′ E., 3213 fathoms; 248, lat. 12° 51′ N., long. 145° 46′ E., 4813 fathoms; and as we approach Guam at Station 249, in 2337 fathoms, we come upon deposits of fine volcanic sand.

No soundings were made by the "Albatross" on the line from Guam to Yokohama, as the line is parallel for a considerable length with that run by the "Challenger" from the Admiralty Islands to Japan. In addition

there are numerous soundings by the "U. S. S. Nero" for a proposed cable line between Guam and a point nearly west in the Philippines, as well as a very complete line from Guam to Japan. These soundings, with a line to the east of Guam also run by the "Nero," give an excellent idea of the topography of that part of the Pacific. The character of the bottom unfortunately is not indicated on the charts issued by the U. S. Hydrographic Office[1] to show the interesting soundings of the "Nero," under commander Belknap, two of which are the deepest soundings as yet taken.

The following is the record of the surface hauls made by the "Albatross."

Station 1. Lat. 31° 10′ N., 125° W. 300 miles from Point Conception. Neither Copepods nor Sagittæ, Collozoum, Pleurobrachia, Euphausia, Macrurans, Hyperia, Schizopods, Thysanopoda, Hyalea, Turris, Dyphies, Agalma, Aglaura, Oceania, Pyrosoma, Salpæ, Carinaria, young fishes.

Station 2. Lat. 28° 23′ N., long. 126° 57′ W. Very poor surface haul. 500 miles from Point Conception. Few Macrurans, Euphausiæ, Collozoum, young flying-fish, transparent Prionotus (?) fish eggs, Aglaura, Velella, Abyla, tentacles of a Siphonophore on the stray line, which could not be identified.

Surface haul. Lat. 28° 11′ N., long. 127° 16′ W. Large Ctenophores like Mertensia; an elongated, flask-shaped Cydippe; Salpæ, Isopods, Pteropods, young fishes, Macrurans.

Station 3. Lat. 26° 18′ N., long. 128° 54′ W. Large blue Copepods. Collozoum, Euphausia, two specimens; Sagittæ, Geryonia, young flying-fish. Very poor haul.

Station 4. Lat. 24° 30′ N., long. 130° 16′ W. Halobates, brilliant red Globigerinæ; Collozoum, three or four species; two large blue Copepods, a few small fishes, young flying-fishes; young Ianthinæ; young Velella.

Station 5. Blue Copepods, brilliant carmine Globigerinæ, Pteropods, Spirialis, Diphyes, Collozoum.

Station 6. Lat. 20° 26′ N., long. 133° 28′ W.; Saphirinæ and a few Copepods; Collozoum, the same as thus far obtained, young flying-fish and other small fishes; Globigerinæ; many small lilac Ostracods (poor haul).

[1] H. O. Charts, 528, 529.

Station 7. Lat. 18° 19′ N., long. 134° 57′ W. Very poor haul. Small Physalia; small blue and black Copepods; Globigerinæ; young flying-fish, and young of other pelagic fishes; fragments of Pyrosoma.

At 8 P. M., made a very successful haul in lat. 17° 32′ N., long. 135° 40′ W., on the same date as at Station 7. Small transparent Taonius, Copepods, Euphausiæ, Sergestes, embryos of Hyperia, Atlanta, and Styliola, Alcyope, Porpita, Halobates, bells of Diphyes and of Agalma, Crystalloides, Sagitta, very large species, Firoloides, 2 species of Salpæ, Collozoum. We collected in great abundance all the species we obtained in the morning at Station 7, from 150 fathoms, and then to the surface.

Station 12. Lat. 12° 07′ N., long. 137° 18′ W. This haul contained Collozoum, and a few Globigerinæ; small blue, yellow, and brown Copepods were quite abundant. At 8 P. M. of same day, in lat. 10° 57.6′ N., long. 137° 35.4′ W., made a surface haul. Euphausiæ were very abundant, small phosphorescent fishes, and many other young surface fish, Copepods, three species of Pteropods, Spirialis, Salpæ, three species of Sergestes larvæ, small Macrurans, Halobates. This haul being so successful, we made a second one immediately after it, and obtained very little; the same things were collected, but fewer in number, and the absence of Euphausiæ in this second trial was especially marked.

Station 13. Lat. 9° 57′ N., long. 137° 47′ W. In this surface haul we collected practically all the so-called deep-sea types which came up in the "Blake" trawl when dragging from 3088 fathoms to the surface. On the surface Porpitidæ were common, as well as flying-fishes; we were evidently in the equatorial current. The net contained very many small Sagittæ, and small Copepods, only a few large ones, Atlanta, Hyalea, Spirialis, Thysanopoda, Nyctophanes, Nematocelis, Stylocheirus. A very young Physalia, the youngest yet observed, was drawn by Dr. Mayer. Young Diphyes. There were no Euphausiæ in this haul. We made a second surface-haul at the same place and obtained the same things and in addition Halobates. Same date, surface-haul at 8.30 P. M., lat. 9° 26′ N., long. 137° 49′ W., very much like that of the previous night, without the surface fishes, only one young fish, Spirialis, Tiedemannia, Cuvieria, Euphausiæ, Amphipods, Sergestes, Hyperia, large blue Copepods, and a few others,

large Sagitta, Collozoum, Globigerinæ, Geryonia, Aglaura; not so many Euphausiæ as on the previous day, when they formed a perfect paste.

Station 14. Lat. 6° 41′ N., long. 137° W. Very good haul. Apparently still in the equatorial current, judging from the amount of animal life in the surface-hauls. Blue Copepods, a large Saphirina, Salpæ in great abundance, the principal part of haul consisted of them; Glaucus, young Cuttle-fish, several species of young pelagic fishes, a fine lot of Collozoum. No Euphausiæ, Sergestes very common, young Physaliæ, Nausithoë, Aegina, Diphyes.

Same day, 8 P. M., lat. 5° 40′ N., long. 136° 47′ W. Huge Pyrosomæ, beautifully phosphorescent, were very abundant, Salpæ, Sergestes, a few Copepods, Euphausiæ, large Hyperidæ, a few transparent Penæids, young fishes, large Appendiculariæ, Cydippe, same species obtained before, Geryonia, Cestum, large Sagittæ, and few smaller ones.

Station 15. Lat. 4° 35′ N., long. 136° 54′ W. Very poor haul. Few Copepods, Diphyes, bells of Agalma, large transparent fish-eggs, a few Sagittæ, Collozoum, and Halobates.

Same day, 8 P. M. Lat. 3° 28′ N., long. 136° 54′ W. A small black, blunt nosed fish, with luminous organs, a small fish with phosphorescent organs, hosts of Salpæ, at least three species, Cydippe, Aglaura, Rhopalonema moving by convulsive jerks of the velum, Turris-like Medusa, small flying-fish, huge Appendicularia houses, small Appendiculariæ, two Copepods and Euphausiæ, Hyperia, Penæus with very long tentacles. Sagittæ, bells of Diphyes and of Agalma, many Radiolarians in the stomachs of Salpæ. It is astonishing how many Radiolarians and Globigerinæ the "Challenger" obtained in the open tow-nets; our experience near the line in the Pacific has thus far been quite the contrary.

Station 16. Lat. 2° 38′ N., long. 137° 16′ W. Poor surface haul. A few Salpæ, Copepods, Argulus, Collozoum, Sagittæ, the same as before; young Physalidæ, the same Medusæ as at Station 15, Turris (?), Euphausia, Penæus, young Balanus larvæ, Diatoms, a fine large Tiedemannia; colder current running to Westward at rate of two knots.

Same day, 8 P. M. Lat. 1° 45′ N., long. 137° 36′ W. Net full of surface animals, mainly small Sagittæ, Appendiculariæ, very many Sergestes, small

Copepods, a few Euphausiæ, Balanus larvæ, small Salpæ, Cydippe, Geryonia, Rhopalonema, a few Collozoum, Liriope hyalinea of Fiji, Halobates, small black phosphorescent fishes, large Pteropod, Cuvieria.

Station 17. Lat. 0° 50′ N., long. 137° 54′ W. The surface haul at this station contained nothing of importance.

Station 18. Lat. 6° 25′ S., long. 138° 59′ W. Surface haul very poor. Collozoum, a few Sagittæ and Copepods, two small fishes.

Station 25. In the channel between Nukuhiva and Washington Islands. Very poor. A few Sagittæ, a blue Copepod, and Collozoum.

Station 26. Lat. 8° 52′ S., long. 139° 52′ W. Very poor haul. Collozoum, Sagittæ, small black Copepods and others, Mysis, Halobates, young Physalia, and Geryonia, — same species as before, — small fish-eggs, many small solitary Salpæ, or isolated zooids, Appendicularia with iridescent tail, Ianthina, Halobates.

Sept. 15. At anchor in Anna Maria Bay, Marquesas. Collected with the electric light a number of large Appendicularia houses, new Diphyes.

Station 30. Lat. 10° 29′ S., long. 141° 52′ W. Many Ianthinæ and Firoloides, Sagittæ, Collozoum, Diphyes, a few Copepods, fish-eggs, small Diodon, Sergestes larvæ, Orbulina in very fine condition, large Appendiculariæ, no Euphausiæ, Agalma bells, Salpæ.

Station 31. Lat. 12° 20′ S., long. 144° 15′ W. Ordinary haul. Sagittæ, two small Copepods, many Lucifer, medium-sized Appendiculariæ, Firoloides, many Ianthinæ with Lepas parasites, Porpita and Physalia quite common; Diphyes bells, Carmaris, perhaps the same species as that described by Haeckel, as found off Peru.

Station 31. 7 P. M., same day. A good surface-haul containing Salpæ, Doliolum, three species of Copepods, black, pink, and red, Lucifer, Phronima, a large red species, a small red crab, adult of a red Zoea collected yesterday; large Sergestes, fine transparent specimens; Atlanta, Rhopalonema, Lyriope hyalina, Diphyopsis.

Station 32. Lat. 13° 37.5′ S., long. 145° 42′ W. Sagittæ, four species of Copepods, Lucifer, Hyperinæ, Firoloides, Salpæ, a large species of Appendicularia, two species of young fishes, Agalma, a new genus of Diphyes allied to a genus collected at the Marquesas.

Station 35. Lat. 14° 42′ S., long. 147° 08′ W. 8 P. M., at anchor off Avatoru Pass. Cydippe, Phronima, Appendicularia, and Copepods.

September 23. Surface-haul in Rangiora Lagoon near anchorage. Many Appendiculariæ, Sagittæ, Cydippe, Rhopalonema, Epenthesis, first time we have found Hydroids. No Crustacea.

It is to be noted that in the Pacific, far away from land, we only meet Narcomedusæ, Cunanthidæ, and the like, while Hydroid Medusæ are found near shores. The same result was obtained by the "Plankton" Expedition.

Station 48. Off Avatoru Pass, Rangiroa. An excellent haul, containing small phosphorescent fishes, Squillæ larvæ, Zoeæ; Penæids, with red at base of antennæ, many Copepods, Euphausiæ, transparent larvæ of many shore genera of Brachiurans and Macrurans, Syllis, Goniodactylus, larvæ of Scillaridæ, Nausithoë, two species of Rhopalonema, Cydippe, Diphyopsis, Pelagia, Octopus, Pteropods, Appendiculariæ, Halobates, Collozoum, Salpæ, Sagittæ.

Station 73. Lat. 17° 27′ S., long. 149° 32′ W. Very poor haul; only obtained one small flounder and one Cyema.

At 7 P. M. on the same day an excellent haul was made, containing large and small Sagittæ, Salpæ, large Appendiculariæ, Agalma bells, Diphyopsis, Rhegmatodes, Stomobrachium, Aglaura, Amphipods, two species of Penæids, one fine Nyctophanes, a red Copepod, blunt-headed black fish with phosphorescent organs, also young of large-headed fish with phosphorescent organs, Sergestes, larvæ of Willemoesia, no Euphausiæ, three species of Pteropods, Cuvieria, Styliola, Alciopa, Collozoum.

Station 133. Lat. 18° 05′ S., long. 142° 23′ W. A very poor haul, containing a small flying fish, Abyla, Diphyopsis, Collozoum.

Station 139. Lat. 18° 08′ S., long. 141° 04′ W. A very poor haul, containing only Pneumodermon larvæ and small Salpæ, a couple of Copepods, Diphyes bells, and Collozoum.

Station 173. Lat. 18° 55′ S., long. 146° 32′ W. A poor haul, with two species of Collozoum, three of Copepods, Diphyopsis, and Agalma bells.

As is shown from the surface hauls made in the Paumotus, the number of pelagic animals is quite small, and even the few successful hauls did not compare in richness with those made while crossing the equatorial current. We had a similar experience with our surface hauls while cruising through

the leeward Society Islands, the Cook, and Tonga Archipelagos, as will be seen from the record which follows: —

Nov. 16. Near the west side of Huaheine. Calm. Very poor haul: a few Copepods, Collozoum, mass of Trichodesmium. At anchor in Hurepiti Bay, Tahaa. By electric light a fair haul was made of Copepods, Polygordius, young Tamoya, Lucifer, many crustacean larvæ, mainly Brachiurans, many Ostracods, Styliola.

Nov. 17. At Bora Bora, 8 P.M., we obtained from the surface haul Ostracods, Lucifer, Appendiculariæ, Sagittæ, Squillæ larvæ, Megalops, small fishes, Macrurans, Ctenophores; very poor in Copepods. A second haul made with electric light contained mainly Crustaceans, specially Ostracods, also Sagittæ and Appendiculariæ.

Nov. 24. Station 183. Lat. 19° 04′ S., long. 167° 41′ W. A very poor haul: a few Collozoum, four small Copepods, one Ostracod.

Nov. 29. A surface haul made at Tongatábu by electric light contained only four Copepods.

Dec. 4. A surface haul at Vavau by electric light brought together quite a number of young fishes, a few Copepods and Schizopods, Halobates, and young Linerges.

Dec. 23. About one mile off shore, off the north entrance to Funafuti. A few Copepods, Collozoum, Tomopteris, pelagic fishes, and two species of Halobates.

Jan. 1, 1900. Off the south shore of Tarawa. Collected by electric light large numbers of embryos of Crustacea and young fishes.

Jan. 5. At Taritari anchorage. Collected by electric light an immense number of Copepods, together with pelagic Annelids, Autolytus, young fishes, and many embryos of shore Macrurans and Brachiurans.

Jan. 18. At anchor, Rongelab. A surface haul by electric light brought a large number of embryos of Crustacea and of young fishes.

Station 222. About one and a half miles south, off the southeast pass, of Rongelab. A surface haul obtained only Collozoum and one blue Copepod.

Jan. 20. At anchor in Likieb lagoon. Surface haul by electric light obtained Autolytus, many Annelids, young fishes, and larvæ of Macrurans and Brachiurans.

Jan. 22. At anchor in Wotje. Surface haul by electric light; obtained mainly young fishes and larvæ of shore Crustacea, a good many Copepods, and a few Annelids.

Jan. 24. At anchor in Arhno lagoon. Made a surface haul by electric light; obtained young Squid, fishes, Sagitta, Bolina, Macruran larvæ, and Copepods.

Jan. 27. A second haul made at the Arhno anchorage by electric light obtained many Squid, young fishes, many Copepods, Nereis and Heteronereis-like Annelids, and larvæ of Macrurans.

Feb. 26. At our anchorage in Truk we obtained a number of phosphorescent Annelids skimming over the surface, appearing as brilliant luminous spots, and extending, as the animal moved rapidly, into long, thin, tortuous lines from one to two feet in length.

We did but little towing at Fiji, where I had done considerable work off Suva during a former visit in the winter of 1897–1898 while cruising through the group in the "Yaralla." The pelagic material collected at that time, as well as the collections made by Dr. Woodworth at Samoa in 1898, will be incorporated with the reports on similar material obtained by the present expedition. We were greatly surprised at the extreme poverty of the surface hauls made within the atolls wherever we anchored in the Ellice, Gilbert, or Marshall Islands, with the exception of a haul made by electric light in Taritari, when the nets came up filled with a swarm of Copepods, with many young Annelids, larvæ of Brachiurans and Macrurans, as well as young fishes.

We had a similar experience when towing in the Carolines in the belt of the trades. In fact, the poverty of the surface fauna of the regions of the Pacific which we traversed (far from land) was very marked, with the exception of the limited tract while crossing the equatorial current, as contrasted to the abundance of animal life found in the Panamic district, or in the track of the Gulf Stream and in the West Indian area.

This renders it far more difficult to obtain data for the bathymetrical and geographical distribution of the pelagic fauna of the Pacific, and until far more extensive material has been brought together, the localization of the surface faunæ of the Pacific realm must be left in a very indefinite state.

All we may assert at present is that there is a great intertropical belt extending north and south of the equator twenty or twenty-five degrees of latitude and reaching from the Central American district west, as far as the East Indian Archipelago. The surface fauna of this extensive area is quite uniform and has a wide geographical range in longitude; while both north and south of it we have the temperate surface fauna, which in latitude passes gradually into a subarctic and subantarctic fauna. The tropical fauna is characterized by the greater number of genera and species and the small number of individuals of each. As we proceed north or south into the temperate or subarctic and subantarctic regions the diversity of the fauna shows a marked diminution in the number of genera and species, with a corresponding increase in the number of individuals of the species characteristic of the temperate and of the more northern or southern belts. As regards the correlation of the fauna of these different regions in depth and in latitude, the material available for such a comparison has not yet been sufficiently worked up.

Hauls made at intermediate depths by the "Albatross."

To supplement the surface hauls the open tow-nets were sent to tow at depths varying from 100 to 400 fathoms, and after having dragged at certain depths they were run up to the surface open, thus mixing the materials which might have been obtained at different depths by closing-nets. One cannot fail to be struck with the fact that the nets sent down to these greater depths did only in very few instances collect any forms which might be said to live in intermediate depths, as compared with those collected in the surface hauls.

At the following stations hauls with the open tow-net (unless otherwise stated) were made by the "Albatross" at definite depths for a limited time, then the open tow-net was dragged to the surface. The legend is as follows, viz.: Station 1. At 300 fathoms and to surface; meaning that the open tow-net was dragged at a depth of 300 fathoms generally twenty to twenty-five minutes, and then dragged to the surface and contents of net examined. Other stations have a corresponding legend. The net was kept practically at the depth indicated by means of the clinometer in use on the "Albatross."

Station 1. Lat. 31° 10′ N., long. 125° W. At 300 fathoms and to surface. Large Copepods, Larvæ of Balanus, Ostracods, Macrurans; the same Oceania and Diphyes as on the surface; Hyalea, Carinaria, a transparent Alciopa; dead Globigerinæ and Orbulinæ.

Station 2. Lat. 28° 23′ N., long. 126° 57′ W. At 350 fathoms and to surface. Tentacles of Siphonophores. Bathyphysa came up entangled on the dredging wire. Gnathophausiæ, Hyperidæ, many Copepods, Euphausiæ, a Scopeloid, large Tomopteris with violet band in middle, and white flappers. Second haul: 100 fathoms and to surface. Remarkable fish with pedunculated eyes, Macrurans, Copepods.

Station 3. Lat. 26° 18′ N., long. 128° 54′ W. At 200 fathoms and to surface. Large blue Copepods, numerous small white Copepods, yellowish-brown Copepods. 660 miles to Point Conception. Collozoum, young flying-fish, Sagittæ, Euphausiæ, Phronima, Firoloides, Hyalea, Cuvieria, Styliola, Geryonia with six canals; very transparent Alcyopidæ.

Station 4. Lat. 24° 30′ N., long. 130° 16′ W. At 500 fathoms and to surface. Numerous large Copepods, blue, brown, and red; one with red anterior part of carapace; small Copepods, red and white; Euphausiæ, Ostracods, Saphirina, small transparent Alciopa, Styliola, a Rhizophysa 12″ long attached to the wire rope; Diphyes bells, Collozoum. Collected nothing which had not been obtained when towing at 200 fathoms.

Station 5. Lat. 22° 42′ N., long. 131° 54′ W. At 150 fathoms and to surface. Many large gray and brown Copepods, large red Copepod, Pteropods, large Sagitta, Diphyes, mutilated Taonius.

Station 6. Lat. 20° 26′ N., long. 133° 28′ W. At 150 fathoms and to surface. Small Copepod with black appendages (subsequently often found), large red and brown Copepods, Cydippe, Collozoum, Globigerinæ, Styliola, Sagitta, Sergestes larvæ, small Taonius, Amphipods, and a large Stenorhynchus.

Station 7. Lat. 18° 19′ N., long. 134° 57′ W. At 150 fathoms and to surface. Fair haul of Copepods, Euphausiæ, Phroninæ, Cystosoma, Sergestes, small black Copepods, large pink Copepods, Firoloides, Sagitta; fragments of a large transparent Solmaris.

Station 12. Lat. 12° 07′ N., long. 137° 18′ W. At 150 fathoms and to surface. Excellent haul, Agalma, Diphyes, large Ægina, all Copepods of

large species; large transparent Amphipod; Salpæ with large red nucleus; large Sagittæ, Collozoum; marked absence of Euphausiæ and other pelagic Macrurans, no Rhizopods on the surface; Pteropods, many Atlanta, Hyalea, Styliola, Cuvieria, Tiedemannia; very active large Ostracod of reddish color and with a transparent shell; Appendiculariæ, Globigerinæ, Amphyon Reynaudi. The Salpæ were full of Radiolarians of the same species as those brought up from the bottom in the sounding-cup.

Station 14. Lat. 6° 41′ N., long. 137° W. At 150 fathoms and to surface. In general the same things as at the surface. Leptocephalus, Salpæ and many Pteropods, Pyrosoma, young fishes, Siphonophore bells, many Squilla embryos, Oxyrhynchus, also Sergestes, not many Copepods, the few collected were very large.

Station 15. Lat. 4° 35′ N., long. 136° 54′ W. At 150 fathoms and to surface. Large Cestum, a few Copepods and Euphausiæ, Eretmocaris, large white Macruran, small Saphirina-like Copepod, the same Salpæ as yesterday, very large Atlanta, Spirialis, Styliola, a few Tomopteris, Sagitta, the remarkable Tunicate, Octacnemus, figured by Moseley, a few colonies of a small Pyrosoma, Globigerinæ, Halobates.

Station 16. Lat. 2° 38′ N., long. 137° 16′ W. At 250 fathoms and to surface. Fine haul. Many Pelagothuriæ, Diphyes, Diphyopsis, Turris, Leptocephalus, young fishes and mollusks, Copepods, Penæids, Euphausiæ, Tomopteris, and other pelagic worms; Pteropods, Hyalea, Atlanta, Styliola, Spirialis, Sagittæ, Salpæ; the Salpæ full of Radiolarians; Collozoum, no Globigerinæ or Radiolarians at surface.

Tanner net, at 330–350 fathoms. In the closed lower bag only a couple of Copepods were obtained. In the open upper bag four species of fishes, Pelagothuriæ, a number of large red Schizopods, Penæids, and large red Copepods, Sergestes, large transparent Phyllodoce with spots on the side, a large Ostracod with chocolate-brown colored shell, all of which have been obtained before at a less depth.

Station 18. Lat. 6° 25′ S., long. 138° 59′ W. At 400 fathoms and to surface. Net carried away; too rough. Fragments of Sigalion, a couple of young fishes, small Octopus, large Copepods, a few Euphausiæ, a large Bentho-

caris, the same that was obtained in the trawl by the "Challenger" (Pl. 123) in a depth said to be two miles deep. We may safely assume that the majority of the Gnathophausiæ and Schizopods are not from the bottom, but live near the surface; also that all Macrurans with swimming appendages are not necessarily from the bottom. Penæids with and without powerful swimming appendages, but long-legged types like Nematocarcinus, come from the bottom. Dr. Moore, who carefully examined the three species of Macrurans we brought up from the unsuccessful trawl, in 3088 fathoms, says they have all been found at less than 100 fathoms. The same may be said of the fishes collected in that haul.

Station 26. Lat. 8° 52′ S., long. 139° 52′ W. At 300 fathoms and to surface. Several red Penæids and so-called deep-sea fishes, Euphausiæ, Sergestes larvæ, Annelids, and fragments of transparent pelagic Annelids, Sagittæ, young Sternoptyx and other species of young fishes, Salpæ, Aglaura, large bells of Diphyes, Penæid with long antennæ, the same as that obtained in haul from 830 fathoms!

Station 27. Lat. 9° 01′ S., long. 140° 04′ W. At 300 fathoms and to surface. Fine lot of Penæids with long antennæ, Scopelids, Euphausiæ, Zoeæ of shore Brachiurans, a fine Nemichthys! so-called deep-sea fish; Leptocephalus, and three other species of small fishes; Actiniæ embryos, Tanais, Agalma bells, Diphyes, and a new genus of Diphyes with opaque bells, a large Pilidium measuring half an inch, Sergestes, Pandalus, a short Tomopteris with marked yellow patches at the base of the flappers.

Station 30. Lat. 10° 29′ S., long. 141° 52′ W. At 300 fathoms and to surface. Two species of phosphorescent fishes, a young Diodon, Euphausiæ, a few Copepods, a large red Zoea, Carinaria, Firoloides, Styliola, Hyalea, a small Siphonophore, Agalma bells, transparent Annelids and the large Pilidium again, Sagittæ, Tomopteris, Alciopa, and other species of worms, Salpæ, Gasteropods in the veliger stage.

Station 32. Lat. 13° 37′ S., long. 145° 42′ W. At 300 fathoms and to surface. Five species of fishes, Euphausia, three species of large Copepods, Lucifer, Sergestes, Oxycephalus, the same large Pilidium as before, Rhopalonema, Diphyopsis, Abyla.

Oct. 5. Off Point Venus, Tahiti. At 350 fathoms and to surface. Atlanta, and small fishes. Wire parted, net inside out.

Station 91. Off Fakarava. At 350 fathoms and to surface. Very poor haul. A Tamoya, the young of the large Charybdea caught off Anaa(?) Euphausia, Sagitta, young fishes, two species.

Oct. 28. Two miles off Marokau (west shore). At 300 fathoms and to surface. Very poor haul. Sagitta, Salpæ, Diphyes, Abyla, large Cuvieria. Among the Paumotus the surface fauna is very poor; we have seen little or no phosphorescence while steaming through the group until on the night when making Aki Aki, when there seemed to be a little more pelagic life, judging by the phosphorescence.

Station 173. Lat. 18° 55′ S., long. 146° 32′ W. Half way from Hereheretue to Mehetia. At 100 fathoms and to surface. Poor haul. Diphyes, Liriope, Euphausia, Abyla, Sagitta, Copepods, Saphirina, Collozoum very abundant, two forms of colonies, Penæids, Tomopteris, Syllis, a small species of Salpæ, large Appendiculariæ. At the same locality, at 300 fathoms and to surface, we obtained exactly the same things, with the addition of a few Pteropods, Cuvieria.

Dec. 23. One mile off the north entrance to Funafuti. At 150 fathoms and to surface. Smooth water, very bright day. Brought up Beroë, Liriope, Bougainvillia, Sagitta, several species of Copepods, pelagic Annelids, Tomopteris, Pteropods, a large pink Appendicularia, Schizopods, Saphirina, Collozoum, a few red Globigerinæ, larvæ of Macrurans and Brachiurans.

At Station 222, about one and one half mile south, off southeast pass into Rongelab. At 150 fathoms, and to surface. Excellent haul. Obtained Firoloides, Sagitta, Pteropods, Criseis, Cuvieria, several species of brilliantly colored Copepods, red, blue; a transparent Argulus-like Crustacean, Collozoum, Solmaris, transparent pelagic Annelids, Taonius, several species of Macrurans, Salpæ, the stomachs of which contained many Radiolarians.

Dr. Woodworth made a few hauls with the Krämer quantitative nets.

Eight of the hauls are pairs, taken inside and outside of lagoons.

One pair, three quarters mile off the east point of Funafuti, at fifteen fathoms in 250 fathoms, and from fifteen fathoms close to bottom, inside of lagoon, half a mile from the village.

One pair, one and a half miles off the south point of Rongelab, at fifteen fathoms in 450 fathoms, and inside at our anchorage, at twelve fathoms one mile from the shore.

One pair, half a mile off South Pass into Likieb, at fifteen fathoms in 468 fathoms, and inside of Likieb Atoll at our anchorage, at ten fathoms.

One pair, one mile off South Pass into Wotje, at 30 fathoms in 482 fathoms, and one mile inside Rurick Pass, at our anchorage, at fifteen fathoms in twenty-two fathoms.

A single haul off the southeast point of Tarawa, in fifteen fathoms in 200 fathoms; a single haul, at our anchorage in Arhno Lagoon, at fifteen fathoms in twenty fathoms.

All these showed an excess of organic life in the lagoon as compared with that obtained outside of the lagoons. It does not strike me as if the results obtained heretofore, or the few data we collected, were of great value in determining the question of the proportion of food supplies to corals growing inside of a lagoon or on its sea faces, either on the weather or lee side.

The conditions inside of a lagoon are very different from those outside, and depend greatly upon the depth of water on the weather rim of the lagoon, the extent of the land-rim, the number and dimensions of the passages leading in and out of the lagoon on the weather or lee side, and the trend of the lagoon as related to the prevailing winds.

In a lagoon which is comparatively shut out from the general circulation of the waters surrounding it, we naturally have conditions radically different from those lagoons in which the prevailing winds drive over the submerged rim of the weather-side a mass of water, pouring into the lagoon all the surface organisms of the adjoining sea. Such a closed lagoon is Pinaki, for instance. The amount of pelagic life which finds its way into its shallow lagoon through the narrow gap communicating with the sea must of necessity be very small compared to the mass of water driven into such a huge lagoon as Wotje, of which so great a part of the outer rim is submerged, with one to six fathoms; and again, quite a different state of things must exist in the interior of a lagoon of which the rim on the

lee side is made up of large islands, and on the weather-side of shallow flats separated by narrow gaps, allowing but a comparatively small amount of water to be driven into the lagoon from that side. In a semi-closed lagoon like Pinaki there are but few corals, when compared to those found in such an open lagoon as Wotje, and there are none growing in the closed lagoon of Niau.

The fact remains that the corals growing on the sea face of an atoll or of a barrier or fringing reef are far more massive and abundant than those which grow inside of the lagoon. While it cannot be denied that the corals of the lagoon are in many localities more numerous in species, yet they never extend to as great a depth, and never have the luxuriant growth or form the colossal heads which characterize those of the sea face.

Furthermore, the amount of animal life, irrespective of corals, which finds its sustenance on the sea face of a reef is very great, and its superabundance does not seem to indicate a lack of food-supply as compared with that existing in the lagoon.

To be of value it seems to me that these quantitative experiments should be accompanied with a comparative statement of the amount of water sifted through each lagoon, as it were, in which the experiments are conducted. And furthermore, the amount of animal life coming to the surface, or living to a depth of ten or fifteen fathoms outside of any atoll, must be fully as fluctuating a quantity in these regions as it is known to be elsewhere, depending upon the season, the time of the day, and atmospheric conditions, all of which are still unknown factors to us, not only in the Pacific, but even at localities where observations on the relative abundance of surface organisms, and the causes which influence it, have been carried on for many years.

The record of the observations of the surface temperatures and of the specific gravities of the sea were in charge of Dr. H. F. Moore. Of course, until the record has been carefully computed, we can compare it only in a very general way with the results obtained in the Pacific by the "Challenger" as tabulated by Dr. Buchanan,[1] and specially with Plate 5

[1] Physics of the "Challenger" Expedition, Vol. I., London, 1884.

of the "Atlas of the Pacific," issued by the German Observatory in 1896,[1] giving the lines of the specific gravity based upon a large amount of material accumulated by a number of exploring expeditions down to 1893.

The observations of the "Albatross" practically agree with Plate 5 of the German Observatory Atlas, showing a gradual increase as we proceed south from San Francisco to the vicinity of the Society Islands and in the Paumotus, with a maximum specific gravity on the line San Francisco to Tahiti. In a general way we found also a somewhat greater salinity in the lagoons, as at Rangiroa, Fakarava, Makemo, in the Paumotus, as well as in the Tongas, Fiji, the lagoons of the Ellice, Gilbert, Marshall, and Carolines, at Funafuti, Taritari, Jaluit, Rongelab, Wotje, Arhno, Ualan, Ponapi, Truk, and Guam in the Ladrones.

As we proceed westward from the Society Islands there is a gradual and very marked diminution in the specific gravity, reaching its minimum in the Fijis. Thence it again diminishes rapidly northward at the Ellice, Gilbert, and reaches on that line its minimum in the southeastern Marshall Islands. It rises again in the northern Marshall Islands and going west from Jaluit is somewhat less along the Carolines, falling again as we go north to the Ladrones, and thence to Japan, with the exception of a slight rise to the west off the Bonin Islands.

The Bottom Deposits collected by the "Challenger" in the Pacific.

The chart given by Murray and Renard,[2] showing in general the nature of the bottom deposits of the Pacific, naturally does not give the interesting details for each sounding, showing the relation of the constitution of the bottom deposits to the depth. As the line run by the "Albatross" shows in a remarkable manner the same correspondence which had been first observed by Sir John Murray between the amount of carbonate of lime present and the depth, I have, for purposes of comparison, collected the data of the principal stations occupied by the "Challenger" in the Pacific, to show how closely the later observations of the "Albatross" agree with the records of the "Challenger."

[1] Deutsche Seewarte, Stiller Ozean, Ein Atlas v. 31 Karten, Hamburg, 1896.
[2] Chart 1: Deep-sea Deposits, "Challenger" Expedition, Murray and Renard.

In the western Pacific the line run by the "Challenger" from the Admiralty Islands to Japan, shows the following:[1]

At Station 220, lat. 0° 42′ S., long. 147° E., 1100 fathoms, Globigerina ooze,[2] seven species of Radiolarians were obtained from the bottom deposit.

The Radiolarians from the deposit at Station 224, lat. 7° 45′ N., long. 144° 20′ E., in 1850 fathoms, were represented by nearly thirty species, and by about sixty species of Foraminifera, 88 per cent of the carbonate of lime of the deposit being represented by pelagic species.

At Station 225, lat. 11° 24′ N., long. 143° 76′ E., in 4475 fathoms, Radiolarian ooze; over 350 species of Radiolarians are noted from the deposit, and ten from the surface. The deposit indicates only a trace of carbonate of lime, while at Station 226, lat. 14° 44′ N., long. 142° 13′ E., in 2300 fathoms, the red clay contains 6.11 per cent of carbonate of lime, and in 2475 fathoms, Station 227, lat. 17° 29′ N., long. 141° 21′ E., only a trace of carbonate of lime occurs, as well as at Stations 228, 229, 230, 231. At Station 229, lat. 22° 01′ N., long. 140° 27′ E., in 2500 fathoms, red clay, the deposit was characterized by numerous Diatoms. At Station 231, lat. 31° 08′ N., long. 137° 08′ E., in 2250 fathoms, blue mud, the number of species of Radiolarians in the deposit was greatly reduced, not more than ten being noted at that station.

It is interesting to note in the line Admiralty Islands to Yokohama that the Globigerina ooze is found in what we may call, in a general way, the equatorial current, between Stations 220 to 224, while the Radiolarians extend as far north as Station 231, taking their greatest development, apparently, in the belt of the trades, from Station 225 to Station 230. On the line from Yokohama to the Hawaiian Islands blue mud was brought up at the first station east of Japan, No. 237, in 1875 fathoms, with 4.45 per cent of carbonate of lime, made up of about 100 species of Foraminifera, 33 per cent of the carbonate of lime in the deposits being made up of pelagic species. The deposit at this station is also characterized by the large number of species of Diatoms it contains. Globigerina ooze was brought up only at Station 246, in 2050 fathoms. At all the other stations

[1] John Murray, Observations at each of the "Challenger" Stations.
[2] See Murray and Renard, Voyage of the "Challenger," Deep-Sea Deposits.

red clay was obtained, with either no carbonate of lime or only a trace of it, except at Stations 241 and 247, the deposit of which contained, in the one case 10 per cent, in the other 17.29 per cent of carbonate of lime. At Station 241, lat. 35° 41′ N., long. 157° 42′ E., in 2300 fathoms, seventy species of Foraminifera were obtained, nearly sixty per cent of which is made up of half a dozen of pelagic species. Nearly fifty species of Radiolarians and twenty-five of Diatoms are also recorded from the deposit at that station.

At the second station from the Japanese coast (Station 238, lat. 35° 18′ N., long. 144° 08′ E.), in 3950 fathoms, red clay, the number of species of Radiolarians in the deposit is limited to two, and it only contains fifteen species of Foraminifera.

At Station 244, lat. 35° 22′ N., long. 169° 53′ E., in 2900 fathoms, red clay, there are mentioned as found in the deposit over thirty species of Foraminifera and nearly 100 species of Radiolarians.

At Station 245, lat. 36° 23′ N., long. 174° 31′ E., in 2775 fathoms, red clay, not more than ten species of Radiolarians are recorded as found in the deposit.

At Station 246, lat. 36° 10′ N., long. 178° E., in 2050 fathoms, Globigerina ooze, where the deposit contains 56.07 per cent of carbonate of lime, over 100 species of Foraminifera are recorded, and 62 per cent of the carbonate of lime is composed of pelagic species.

At Station 247, lat. 35° 48′ N., long. 179° 57′ W., in 2530 fathoms, red clay, ten species of Radiolarians are recorded. A few more species of Radiolarians are recorded at Station 250, lat. 37° 49′ N., long. 166° 47′ W., in 3050 fathoms, red clay, together with about thirty species of Diatoms. At the next station, in 2950 fathoms, Diatoms were also common. Radiolarians are limited to nine species in the deposit of Station 252, lat. 37° 52′ N., long. 160° 17′ W., in 2740 fathoms, red clay.

At the northeasternmost point reached by the "Challenger" in the Pacific (Station 253, lat. 38° 09′ N., long. 156° 25′ W.), in 3125 fathoms, red clay, forty species of Foraminifera are recorded, four of which are pelagic, while the number of species of Radiolarians has increased to about sixty. On the line due south from Station 253 in the direction of the

Hawaiian Islands, fifteen species of Foraminifera, three of which are pelagic, and eight species of Radiolarians are recorded from Station 256, lat. 30° 22′ N., long. 154° 56′ W., in 2950 fathoms, red clay, and in forty fathoms, off the Honolulu reef, eighty-two species of Foraminifera are recorded in the deposit, only 3 per cent of which is made up of seven pelagic species.

The line from Yokohama east to Station 253, lat. 38° 09′ N., long. 156° 25′ W., and thence south to the Hawaiian Islands, is marked for the great number of Radiolarians recorded in the deposits of the different stations, as well as for the number of surface Radiolarians. It will be noticed that the above line follows the general trend eastward of the Japanese current and that the fauna of the bottom appears to be far more abundant in the track of this great oceanic current than in the line running south of Japan, where no great oceanic currents occur.

On the "Challenger" line, Hawaii to Tahiti, which corresponds more to the "Albatross" line, only two of the soundings (Station 270, lat. 2° 34′ N., long. 149° 09′ W., and 271, lat. 0° 33′ S., long. 151° 34′ W.) indicate Globigerina ooze, and both of them are far beyond the depth at which such deposits are usually met with. The "Albatross" had a similar experience at Stations 14, lat. 6° 41′ N., long. 137° W., in 2776 fathoms; 16, lat. 2° 38′ N., long. 137° 16′ W.; 17, lat. 0° 50′ N., long. 137° 54′ W., in 2440 and 2463 fathoms. The above-mentioned soundings of the "Challenger" were in 2925 and 2425 fathoms, and both in the belt of the equatorial current. With the exception of the stations nearest the Hawaiian Islands and Tahiti, which showed a deposit of volcanic mud (Stations 262, 263, and 278), the other stations on that line were all red clay, with little or no trace of carbonate of lime. Though Station 269, lat. 5° 54′ N., long. 147° 02′ W., in 2550 fathoms, approaching Stations 270, lat. 2° 34′ N., long. 149° 09′ W., and 271, lat 0° 33′ S., long. 151° 34′ W., contained 20 per cent of carbonate of lime, made up of more than thirty species of Foraminifera, seven of which were pelagic species, composing about 85 per cent of the carbonate of lime; the rest of the deposit consisting of over sixty species of Radiolarians and over eighty species of Diatoms.

Of the Globigerina ooze Stations No. 270, 2925 fathoms, contained 71.47 per cent of carbonate of lime, and 271, in 2425 fathoms, over 80 per cent;

the latter deposit containing over ninety species of Foraminifera, no less than eighteen of which are pelagic and make up 86 per cent of the deposit. Yet at this station nearly 600 species of Radiolarians are recorded by Haeckel as occurring in the deposit, and about thirty species of Diatoms. The station south of the equatorial belt (272, lat. 3° 48′ S., long. 152° 56′ W., in 2600 fathoms) also contained 10.19 per cent of carbonate of lime, and Station 273, lat. 5° 11′ S., long. 152° 56′ W., in 2350 fathoms, still further south, only 2 per cent; the number of species of Radiolarians occurring in the deposit at Station 272 being reduced to about 270 in number and to about 110 at Station 273. At Station 274, lat. 7° 25′ S., long. 152° 15′ W., the carbonate of lime is nearly 4 per cent and the Radiolarians in the deposit number over 175 species.

In 2350 fathoms, Station 276, lat. 13° 28′ S., long. 149° 30′ W., there is 28.28 per cent of carbonate of lime in the red clay, and over 110 species of Foraminifera, sixteen of which are pelagic and make up 88 per cent of the carbonate of lime. Station 277, in 2325 fathoms, has over 9 per cent of carbonate of lime. Station 278, lat. 17° 12′ S., long. 149° 43′ W., 1525 fathoms, over 20; and other stations in the vicinity of the volcanic mud contain a varying amount of carbonate of lime. At Station 279 it contains nearly sixty species of Foraminifera, four of which are pelagic and make up 33 per cent of the carbonate of lime.

On the line from Tahiti to Valparaiso the soundings (Stations 281–282) in red clay south of Tahiti, though not more than 2450 fathoms in depth, show but a trace of carbonate of lime, while the soundings to the eastward, somewhat less in depth but in Globigerina ooze, carry from 65 to 26 per cent, and are in the line of the southeast trades (Station 283, lat. 26° 09′ S., long. 145° 17′ W. to 286, lat. 33° 29′ S., long. 133° 22′ W.). There are nearly forty species of Foraminifera recorded from the deposit of Station 280, south of Tahiti in 1940 fathoms, thirteen of which are pelagic species, making up 84 per cent of the carbonate of lime, and at Station 284, lat. 28° 22′ S., long. 141° 22′ W., there are eighty species noted as found in the deposit in 1985 fathoms, sixteen species of which are pelagic, making up 74 per cent of the carbonate of lime, which constitutes 65 per cent of the deposit. In a somewhat deeper station, 285, lat. 32° 36′ S., in 2375

fathoms, red clay, and with 26.25 per cent of carbonate of lime, the Foraminifera recorded are reduced to fourteen species, only one of which is pelagic and yet makes up 76 per cent of the carbonate of lime. The Foraminifera are accompanied by about fourteen species of Radiolarians. At Station 286, lat. 33° 29′ S., long. 133° 22′ W., 2335 fathoms, with 25.13 per cent of carbonate of lime in the red clay, there are sixty species of Foraminifera, seven of which are pelagic, constituting 60 per cent of the carbonate of lime.

At Station 288, lat. 40° 03′ S., long. 132° 58′ W., in 2600 fathoms, over forty species of Radiolarians are recorded from the surface, only six at Station 289 (2550 fathoms), and four at Station 290 (2300 fathoms), nearly twenty at Station 291, lat. 39° 13′ S., long. 118° 49′ W., in 2250 fathoms. When we come again to the Globigerina ooze stations, containing from 5 to 71 per cent of carbonate of lime in the deposit, we find nearly sixty species of Foraminifera. At Station 293, lat. 39° 04′ S., long. 105° 05′ W., in 2025 fathoms, with nearly 45 per cent of carbonate of lime, ten species of Foraminifera are pelagic and constitute 78 per cent of the carbonate of lime, accompanied by sixteen species of Radiolarians. At Station 295, in 1500 fathoms, though in 38° south latitude, Juan Fernandez distant nearly 800 miles, eighteen species of Radiolarians were collected at the surface. Five species of surface Radiolarians extended even to Station 298, lat. 34° 07′ S., long. 73° 56′ W., in 2225 fathoms not more than 120 miles from Valparaiso; and over twenty-five species of Radiolarians are recorded from the deposit of that station in blue mud mixed with over twenty species of Diatoms.

At Station 296, lat. 38° 06′ S., long. 88° 02′ W., in 1825 fathoms, Juan Fernandez distant about 500 miles, over eighty species of Foraminifera are recorded from the Globigerina ooze, fifteen of which are pelagic and make up 85 per cent of the carbonate of lime, of which 64.34 per cent is contained in the deposit, together with six species of Radiolarians.[1]

South of Valparaiso to the Gulf of Peñas the Globigerina ooze is marked again for the great number of species of Foraminifera recorded from the

[1] For the distribution of the bottom deposits in the Pacific, see Chart 1 Deep-sea Deposits, "Challenger" Expedition, by Murray and Renard.

deposits at Stations 299, 2160 fathoms; 300, 1375 fathoms; 302, 1450 fathoms, accompanied by a small number of Radiolarians. At Station 300 there are over 140 species of Foraminifera found in the deposit and nearly fifty species of Radiolarians. Only five of the species of Foraminifera are pelagic, yet they make up 83 per cent of the carbonate of lime which constitutes over 54 per cent of the deposit at that station.

The Surface Organisms observed by the "Challenger" in the Pacific.

A comparison of the surface animals taken from the records of the "Challenger" with those obtained by the "Albatross" can at present only show in a very general way their distribution.

The observations of the "Challenger" have not as yet been tabulated with reference to the geographical range of the surface organisms.[1] It is hoped that a beginning may be made when the records of the present Expedition of the "Albatross" are properly arranged. It will be practicable, then, to give some general idea of the distribution of such types as the transparent Annelids, the Pteropods, the Salpæ, and other Tunicates, the pelagic fishes, and Cephalopods. But by far the greatest mass of material relating to surface animals consists of the pelagic Crustacea, the greater number of which consist of the Copepods; next come the Schizopods and Macrurans, the Brachiurans being comparatively few in number. The Ostracods are also fairly numerous. From a cursory examination we can state that the surface fauna of the tropical Pacific has a very wide geographical range, a great many of the species reaching from the coasts of Central America to the shores of the western Pacific.

On the "Challenger" line, Admiralty Islands to Japan, at Station 220, lat. 0° 42′ S., long. 147° E., the surface haul was characterized by Diatoms, Globigerinæ, Dyphies, Siphonophores, Sagitta, Alciopa, Saphirina, Copepods, Hyperia, Oxycephalus, Lucifer Zoëæ, Pteropods, Appendicularia, Salpæ, Doliolum, and young fishes.

At Station 221, lat. 0° 48′ N., long. 148° 41′ E., red clay, in 2650 fathoms, a number of Diatoms were obtained from the surface, as well as Globigerinæ, Schizopods, Macrurans, Cephalopods, young fishes, and much

[1] John Murray, Bathymetrical and Geographical Distribution.

the same species of Copepods, Annelids, Siphonophores, Pteropods, and Tunicates, as in Station 220; a very similar assemblage of surface animals was also obtained at Stations 222, 223, 225, 226, 227, 228, 229, 230, 231, as far as Japan, varying somewhat in the relative abundance of Diatoms, Radiolarians, Globigerinæ, Copepods, Pteropods, Tunicates, and Annelids.

At Station 225, lat. 11° 24′ N., long. 143° 16′ E., the surface fauna, as noted by Dr. Willemoës Suhm, was especially rich, and the same may be said of Station 230, lat. 26° 29′ N., long. 137° 57′ E.; at Station 229, lat. 22° 01′ N., long. 140° 27′ E., Velella, Porpita, Ianthina, and Glaucus make their appearance, having been but seldom taken before on the way from the Admiralty Islands. At Station 231, near the Japanese coast, the character of the water changed, and the tow-nets were filled with Diatoms and Noctilucæ, and the proximity of a land mass was clearly indicated by the change in the surface fauna.

As regards the surface organisms on the "Challenger" line, — Japan to Hawaii, — at Station 237, lat. 34° 37′ N., Long. 140° 32′ E., off the coast of Japan, no less than seventeen species of Radiolaria are recorded from the surface, together with Copepods, Pteropods, Tunicates, and young fishes as well as Annelids, Siphonophores, Ctenophores, Sagittæ, Euphausia, Lucifer, Cyprinidæ, Cuttle fish, Noctiluca, Diatoms, and Globigerinæ; very much the same surface organisms occur at Stations 238, lat. 35° 18′ N., long. 144° 08′ E., where the character of the hauls was again quite oceanic; 239, 240, lat. 35° 20′ N., long. 153° 39′ E., where Copepods were specially numerous; 241, 242, 243, lat. 35° 24′ N., long. 166° 35′ E., with the addition of Halobates, Appendiculariæ, Doliolum, Saphirinæ, Phronima, Phyllosoma, Tomopteris, Oxycephalus, Orbulina, Hastigera, and Diatoms in varying quantities.

At Station 244, lat. 35° 22′ N., long. 169° 53′ E., the number of species of surface Radiolarians recorded is not less than forty-five. These have diminished again to thirteen at Station 245, lat. 36° 23′ N., long. 174° 31′ E. There are also about the same number recorded from Stations 247, lat. 35° 48′ N., long. 179° 57′ W.; 248, 249, lat. 37° 59′ N., long. 171° 48′ W.; 250, 252, lat. 37° 52′ N., long. 160° 17′ W., and 253; though at the last station the surface Radiolarians have increased in number to over thirty species. At Stations 254, lat. 35° 13′ N., long. 154° 43′ W., 255, 256, lat.

30° 22′ N., long. 154° 56′ W., Physalia appears, and the Radiolarians vary from twelve to seventeen species. At Station 257 there are not more than four species recorded for the surface, off Molokai there were not more than five surface Radiolarians obtained, and at Station 260, in the centre of the Hawaiian group, there are recorded from the surface: Diatoms, Globigerinæ, many Radiolarians, and other pelagic animals, such as Medusæ, Siphonophores, Sagittæ, Annelid larvæ, Copepods, Hyperids, Euphausia, Pteropods, Tunicates, and Gasteropod larvæ, though in the other groups of pelagic animals there has been, as a general rule, a very marked uniformity in the surface hauls.

The (open) tow-nets at Station 241, lat. 35° 41′ N., long. 157° 42′ E., were sent to sixty fathoms, and at Station 246 they were sent into deep water, and when brought up contained all the things found at the surface and additional Radiolarians different from those found at the surface.

At Station 247, depth 2530 fathoms, lat. 35° 48′ N., long. 179° 57′ W., the (open) tow-nets were sent down to 1200 and 1500 fathoms, and many Radiolarians "abundant in deposits, but only *rarely* taken in the surface nets" (the italics are mine). On the surface at Station 249, lat. 37° 59′ N., long. 171° 48′ W., the stomachs of the Cirriped Zoëæ were filled with Coccospheres, Coccoliths, Rhabdospheres and Rhabdoliths, and their excrements were composed of masses of these small Algæ and Diatoms. The stomachs of Euphausiæ contained the remains of Acanthometræ and Diatoms.

At Station 250, lat. 37° 49′ N., long. 166° 47′ W., the tow-nets attached to the trawl "which must have towed for a time at a depth of from 300 to 600 fathoms," contained Challengeridæ, Tuscaroridæ, and the like, which were not found in the tow-nets dragged within thirty fathoms of the surface.

At Station 251, lat. 37° 37′ N., long. 163° 26′ W., Velella was very abundant again. At Station 254, lat. 35° 13′ N., long. 154° 43′ W., a tow-net haul was made in 100 fathoms containing Challengeridæ. Murray again says, at Station 257, distant 402 miles from Oahu, lat. 27° 33′ N., a haul of the tow-net from 500 fathoms "brought up Globigerina, Orbulina, Pulvinulina, Phæodaria, and other Radiolaria *not usually observed at the surface*" (the italics

are mine). At Station 259, in 2225 fathoms, 133 miles from Oahu, the tow-nets were sent down to 1000 fathoms, but it does not seem to me from the lists of the organisms brought up that they include any types not found near or at the surface elsewhere in less than 250 fathoms, and they were probably obtained in the upper belts.

The surface organisms of the line Hawaii to Tahiti are marked by the large number of species of surface Radiolarians collected specially at Stations 270, 271, in the line of the equatorial belt, and immediately north and south of it at Stations 268, lat. 7° 35′ N., 269, and 272–274, lat. 7° 25′ S. At Station 268 there were collected nearly sixty species of Radiolarians from the surface; at Station 269 about fifty species; at Station 270 the number of species of pelagic Radiolarians had increased to over eighty; and at Station 271 no less than 400 species of Radiolarians are recorded from the surface. At Station 272 the surface Radiolarians had decreased to about 120 species; at Station 273 to about seventy-five species; and at Station 274 the species had increased again to about 120 in number; and at Station 284, south of Tahiti, in nearly 30° south latitude, not more than seven species of Radiolarians were collected at the surface, about the same number which were collected at the surface at Station 262, in latitude 20° N., near Hawaii. At Station 263, lat. 17° 33′ N., long. 153° 36′ W., the surface Radiolarians had increased in number to nearly twenty species; at Station 265, lat. 12° 42′ N., long. 152° 01′ W., to nearly forty species, and at Station 267, lat. 9° 28′ N., long. 150° 49′ W., to fifty, the number of species gradually increasing towards the equatorial current belt.

As regards the other surface animals noted by the "Challenger," they consisted of Diatoms, Pyrocystis, Noctiluca, Globigerinæ, Orbulinæ, Pulvinulinæ, Diphyes, and other Medusæ, Siphonophores, Sagitta, Echinoderm larvæ, and Zoëa, near the Hawaiian Islands; Euphausia, Sergestes, Saphirina, Copepods, Amphipods, Phronimids, Hyperids, Oxyrhynchus, Pteropods, Appendiculariæ, Alciopa, Annelids and their larvæ, Tomopteris, Salpæ, Ianthinæ, young fishes, Sternoptyx, Scopelids, Cephalopods, Ctenophoræ, Halobates, Coccospheres, Rhabdospheres, Ostracods, Hyalea, Spirialis, Styliola, Tiedemannia, Stomatopods, Schizopods, Carinaria, Firoloides. These

genera occur, of course, in different combinations both in number of species and abundance of specimens at the stations occupied, but none of them were very marked types, or types which had not a wide geographical distribution in the tropical Pacific, as can be noted by comparing the above list with the notes of the contents of the surface hauls made by the "Albatross" in a nearly parallel line, but several hundred miles to the eastward.

As has been shown, p. 94, from the examination of the bottom deposits, a large number of pelagic Foraminifera were obtained by the "Challenger" on the line Tahiti to Valparaiso, as well as pelagic Radiolarians. Going south from Tahiti, the "Challenger" obtained three species of Radiolarians on the surface at Station 282, lat. 23° 46′ S., long. 149° 59′ W., seven at Station 284, lat. 28° 22′ S., long. 141° 22′ W., and no less than forty-two at Station 288, lat. 40° 03′ S., long. 132° 58′ W., the point at which the "Challenger" turned east toward Valparaiso, distant nearly 3000 miles. Along that line which runs somewhat north of the current setting east, in a somewhat higher latitude, the number of surface Radiolarians collected was quite remarkable. At Station 289, lat. 39° 41′ S., long. 131° 23′ W., seven species are enumerated, four from Station 290, lat. 39° 16′ S., long. 124° 07′ W., eighteen at Station 291, lat. 39° 13′ S., long. 118° 49′ W., the same number at Station 295, lat. 38° 07′ S., long. 94° 04′ W., and five at Station 297, lat. 37° 29′ S., long. 83° 07′ W.

The other surface organisms found by the "Challenger" going south from Tahiti to Station 288, in lat. 40° 03′ S., consisted of Pteropods, Diatoms, Hastigerinæ, Acanthometræ and other Radiolarians, Siphonophoræ, Ctenophoræ, Echinoderma larvæ, Sagitta, Cyprinida, Saphirina, Copepods,[1] Euphausia, Sergestes, Lucifer, Atlanta, Appendicularia, Scopelids, Halobates, Clio, Coccospheres, Rhabdospheres, Globigerinæ, Alciopa, Tomopteris, Salpæ, young Lamellibranchs, Phronimids, Hyperids, Stomapod larvæ, Thysanopoda, Benthocaris, Medusæ, Ostracods,[2] Amphipods, Schizopods, Doliolum, Scopelids.

On the line from Station 288 to Valparaiso the surface organisms, other

[1] The Copepods increased as the "Challenger" went south from Tahiti.

[2] The number of Ostracods at Station 296, lat. 38° 06′ S., long. 88° 02′ W., is very striking.

than the pelagic Foraminifera and Radiolaria, did not present any peculiar types; they were the usual pelagic types of the Pacific, such as: Siphonophores, Copepods, Amphipods, Pteropods, Cephalopods, Salpæ, Diatoms, Pelagia, Sagitta, Ostracods, Pelagic Annelids, Tomopteris, Hyperids, Sergestes, Euphausia, Lucifer, Atlanta, Appendicularia, Doliolum, Coccospheres, Rhabdospheres, Pulvinulina, Sergestes, Alciopa, Macrura, Scopelus, Ctenophoræ, Cyprinida, Phronima, Stomatopods, Ianthina, fish eggs, young fishes, Velella, Physalia, Ostracods, Macruran larvæ, Schizopods, Doliolum. This line is also characterized by the great number of Diatoms collected, and at Station 298 Sir John Murray says that "on the whole there was a great change in the general character of the surface fauna, pointing to the nearness of a great continent similar to what was observed off Japan and elsewhere."

The Bathymetrical Range of the Pelagic Fauna.

With regard to the bathymetrical range of the so-called intermediate fauna, the following notes are suggested by the records of the "Challenger" deep tow-net hauls in the Pacific.

At several of the stations the open tow-nets were hauled at a depth of 200 fathoms, and Challengeridæ and other Radiolarians not found at the surface were collected. It does not follow, because the tow-nets attached to the trawl and the weights brought up similar organisms to those obtained at 200 fathoms or more from the surface, that these types are found living all the way from the surface to the bottom, different species recurring at sundry bathymetrical ranges. The open nets attached to the trawl and weights contained, according to the lists given by Murray, only such genera as were also collected by nets sent down to less than 250 fathoms from the surface, and were probably caught by the trawl nets while passing through the upper strata. The experience of Hensen and of Chun has been like that of the earlier expeditions of the "Albatross," as well as the present one, that at the depth of 250 fathoms there is a very marked decrease in the number of organisms collected as compared with those living in a belt nearer the surface. It does not appear from the data given by Sir John Murray that there is any proof of the exist-

ence of the belts of bathymetrical range of pelagic organisms invented by Haeckel, based by him on data of the "Challenger." On the contrary, I would interpret the data of the "Challenger," as well as the results I have obtained in this and former expeditions, and those of the "National" and "Valdivia" Expedition, as showing that within a certain distance from the bottom, at sea, far from continental areas, there is a free-swimming fauna related to that found on the bottom; and that the pelagic fauna, so-called, away from the continents, where the surface fauna is a mixture of shore embryos and of pelagic animals derived from a comparatively short distance from the shore, extends to a very limited depth from the surface,—three hundred fathoms, or thereabout, indicating, from our present knowledge, the limit to which the so-called intermediate fauna extends; many of its members coming occasionally to the surface or near it, and the members of the surface fauna often dropping to considerable depths from disturbing atmospheric causes; near the surface these two faunæ thus become mixed to a certain extent. From my earlier observations, I was inclined to place the lower limit of bathymetrical range of the surface organisms somewhat too high, though even at that limit the pelagic fauna is already greatly reduced in numbers, as has been noticed also by subsequent observers.

NEWPORT, R. I.
October 25, 1900.

REMARKS ON THE BOTTOM DEPOSITS (Plate 1a).

By Sir JOHN MURRAY, K.C.B.

Our knowledge of the deposits covering the floor of the tropical Pacific has been much increased by an examination of the soundings taken by the U.S.S. "Albatross" in 1899 and 1900, under the direction of Mr. Alexander Agassiz. It is true that no new type of deep-sea deposit has been discovered, but the distribution of the deposits has been considerably modified. The principal result, perhaps, is the enormous extension, towards the east, of the Radiolarian Ooze area discovered by the "Challenger" between 5° and 15° N. lat. and 145° and 155° W. long. Our examination of the samples recently collected, and of those collected in 1891, by the "Albatross," seems to show that this Radiolarian Ooze area extends uninterruptedly through about 85° of long. into the Gulf of Panama (where it occurs in comparatively shallow water), forming a band varying in width from 5° to 12° of lat. Another result is the eastern extension also of the Globigerina Ooze area at the equator, and the introduction of Pteropod Ooze around the coral islands of the Paumotu and Marquesas groups. The numerous soundings taken by the "Albatross" among the coral island-groups show that in many cases deep water, where the bottom is covered by Red Clay, approaches very close to the islands, but a curious circumstance regarding the samples collected in the vicinity of the coral islands is the large proportion of very small samples, from which all fine clayey and calcareous material has apparently been washed away during process of collection, so that it is often impossible to say, from the insufficient quantity of incoherent material at our disposal, what the precise condition of the deposit *in situ* may be. The "Albatross," like the "Challenger," crossed the typical Red or Chocolate Clay area, the trawl having, at Station 173 in lat. 18° 55′ S., long. 146° 32′ W., 2440 fathoms, brought up a large supply of stiff choco-

late clay, containing much Manganese in the form of larger and smaller nodules and small grains, and many sharks' teeth.[1]

A peculiar assortment of large continental rock fragments more or less impregnated and covered with Manganese was brought up by the trawl at Station 2, lat. 28° 23′ N., long. 126° 57′ W., 2368 fathoms, 450 miles from Guadalupe Island, the nearest land, where the deposit is an extremely pure Red Clay. These look like fragments transported by ice.

A comparison of this map with the map published in the "Challenger" Report on Deep-Sea Deposits in 1891 shows at a glance that a large mass of information bearing upon the distribution of marine deposits has been collected in the interval. From the numerous surveys made under the auspices of the British Admiralty in the S. W. Pacific, and northeastward to the Sandwich Islands and the American coast, in connection with the British cable between Australia and British Columbia, from the work of the "Albatross" and other ships of the U. S. Navy and U. S. Fish Commission, and from other sources, we have derived much information both regarding the depth and the deposits of the Pacific. The chief modifications on the deposit map of 1891 are,—

(1) The increased area occupied by the Radiolarian Ooze, in lat. 3° to 12° N., extending from long. 165° to 80° W., and also in lat. 8° S. to 6° N. and long. 162° to 177° W.

(2) The alterations in the form of the Globigerina Ooze areas, which are now, in the vicinity of the Coral Islands, more circumscribed, while the Red Clay is proportionally increased in area and more closely approaches the islands.

(3) The introduction of Pteropod Ooze in many localities not indicated on the earlier map; and

(4) The introduction of a band of Diatom Ooze in the extreme North Pacific Ocean, extending from off Yezo Island, Japan, hugging the Kurile and Aleutian Islands, to off Vancouver Island, British Columbia. The existence of this Diatom Ooze band was recognized during the examination

[1] It is rather surprising that no Cetacean bones are included in the material from this Station, indeed among the material sent to us for examination no Cetacean bones have been observed, although Mr. Agassiz mentions having obtained them at Stations 2 and 13.

recently of two series of deposit-samples, the one collected a quarter of a century ago by the U.S.S. "Tuscarora," the other collected in 1890 by the U.S.S. "Albatross," and it bears striking evidence to the bipolar distribution of the pelagic Diatoms whose frustules fall to the bottom in such numbers as to form continuous bands of Diatom Ooze on the seaward borders of the Blue Mud areas both in the far south and, on a smaller scale, in the far north.

EXPLANATION OF THE PLATES.

PLATE 1.

Track of the "Albatross" from San Francisco to Yokohama.

PLATE 1a.

Map of deposits of the Tropical Pacific. Prepared by Sir John Murray.

PLATE 1b.

Bathymetrical chart of the Central Pacific Ocean. Prepared by Sir John Murray.

PLATE 2.

Track of the "Albatross" from San Francisco to the edge of the Marquesas Plateau, showing the position of the "Moser" Basin. Stations 1 to 22.

PLATE 3.

Track of the "Albatross" through the Marquesas Islands. Stations 19 to 30.

PLATE 4.

Track of the "Albatross" from the Marquesas Islands to the Paumotu Archipelago (Ahe). Stations 29 to 34.

PLATE 5.

Track of the "Albatross" through the Paumotu Archipelago and the Society Islands. Stations 32 to 180.

PLATE 6.

Track of the "Albatross" from the Society Islands to Aitutaki (Cook Archipelago) and Niue, November 18 to 25, 1899. Stations 181 to 183.

PLATE 7.

Track of the "Albatross" from Niue to the Tonga Islands and Lau Group (Fiji). Stations 184 to 189.

PLATE 8.

Track of the "Albatross" through the Fiji Islands, December 6 to 20, 1899. Stations 189 to 193.

PLATE 9.

Track of the "Albatross" from the Fiji Islands, through the Ellice Islands, December 20–29, 1899. Stations 194 and 195.

PLATE 10.

Track of the "Albatross" through the Gilbert Islands, December 29, 1899, to January 7, 1900. Stations 196 to 208.

PLATE 11.

Track of the "Albatross" from the Gilbert Islands to Jaluit, through the Marshall Islands and to Kusaie and Ponape (Caroline Islands). Stations 208 to 240.

PLATE 12.

Track of the "Albatross" through the Carolines from Station 240 to Guam. Stations 240 to 249.

PLATE 13.

Track of the "Albatross" from Guam to Yokohama, February 25 to March 4, 1900. Stations 248 and 249.

PLATE 14.

1. Section across the "Moser" Basin from San Francisco Cal. to Nukuhiva, Marquesas Islands.
2. Section across the Marquesas Islands Plateau.

PLATE 15.

1. Section across the basin separating Nukuhiva (Marquesas Islands) to Rangiroa (Paumotus Islands).
2. Section across the channel separating Makatea (Paumotu Islands) from Tahiti (Society Islands).
3. Section from Makemo to Takume across Taenga and Raroia (Paumotu Islands).
4. Section from Anaa to Kauehi, across Fakarava (Paumotu Islands).
5. Section from Rangiroa to Matahiva across Tikehau (Paumotu Islands).
6. Section across Rangiroa (Paumotu Islands) from off Ahe.

PLATE 16.

1. Section across channel separating Plateau upon which are Niau and Apataki from Makatea. Paumotu Islands.
2. Section from Makemo and Hikueru across Ravahere Strait to Hao to Aki Aki and Plateau of Nukutavake and Pinaki.

PLATE 17.

Section across channels separating Plateau upon which are situated Tahanea, Tuanake, and Makemo from Anaa and from Takume (Paumotu Islands).

PLATE 18.

1. Section across channel separating Nukutipipi and Pinaki (Paumotu Islands).
2. Section along a line running about southeast from Tahiti to Mehetia to Hereheretue, Anu Anuraro, Anu Anurunga, and Nukutipipi.

PLATE 19.

Section from off Rota (Ladrone Islands) to Miaki, South of Cape King, Japan, showing the very irregular depth of the bottom in a line parallel to the volcanic islands of that region. From the soundings of the "Challenger" and of the U.S.S. "Nero." H. O. chart No. 529.

Figures of Manganese Nodules . . . . . to face page 5.

1.	Station	13	Lat.	9° 57′	N.,	Long. 137° 47′	W.;	2690 fathoms.
2–4.	"	173	"	18° 55′	S.,	" 146° 32′	W.;	2440 "
5 6.	"	2	"	28° 23′	N.,	" 126° 57′	W.;	2368 "

All figures are natural size.

"ALBATROSS" TROPICAL PACIFIC EXPEDITION.

PLATE 1.

TRACK OF THE "ALBATROSS"

SOUNDINGS IN FATHOMS.

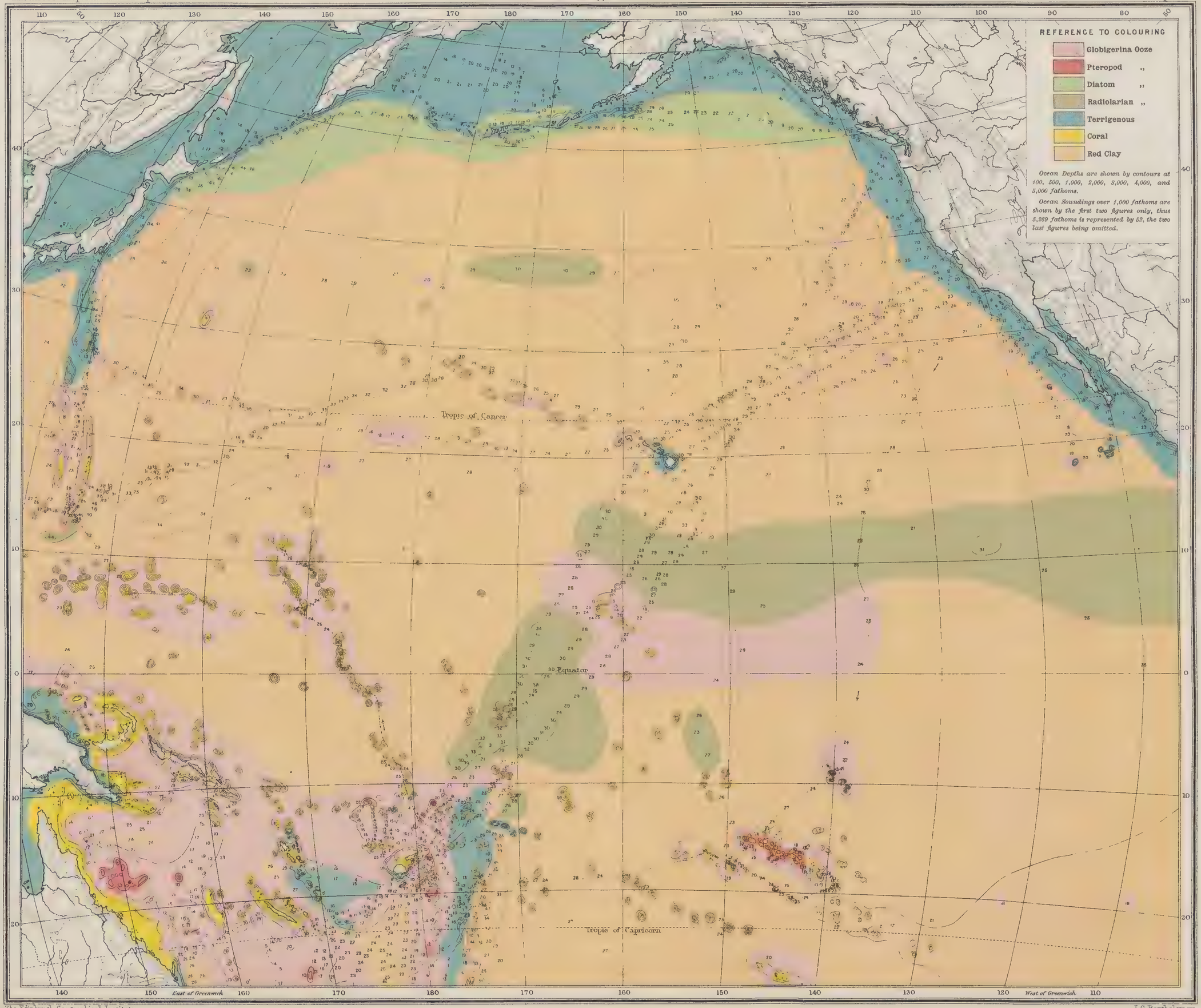
JAPAN IS.
Volcano Is
Hachijo
Bayonnaise I
Lots Wife
Rosario I
BONIN IS
Forfana I
Volcano Is
St. Augustino
Farallon de Pajaros
Assumption I
Agrigan I
Pagan I
Alamagan I
Guiguan I
Sariguan I
Saipan I
Tinian I
Rota I
MARIANA OR LADRONE ISLANDS
Guam or Guajan I
Alligator Sht
Uluthi or Mackanzie Is
Feys
Ngoli
Yap
Sorol Is
Palao or Pelew Is
Kajangle
Arobelltaob
Korror
Pilliu
Angaur
Namonuito Is
Hall Is
Wolea
Martires
Truk
Oraluk
Losap
Senyavina Is
Moldi
Ponapi
Namotuk Is
Mortlock Is
Zuderby Is
Pingelap
Kusaie
CAROLINE ISLANDS
Ujelang
Eniwetoke
Bikini Is
Rongerlap Is
Bikar
Utirik
Likieb
Mejit
Wotje
Kwajalong
Menschikov
Elmore
Arno
Mulgrave
Jaluit
Ebon
MARSHALL ISLANDS
RATACK CHAIN
RALICK CHAIN
Taritari
Apaiang
Maraki
Maiana
Kuria
Apamama
Nonuti
Taputeuea
Nukunau
Onoatoa
Arorai
Tamana
GILBERT IS
Nauru
Pleasant I
Howland I
Nantucket I
Jarvis I
Gaspar Rico
Wakes Is
Johnston I
Morell I
Byar
Cure I
Midway Is
Pearl Rf.
Lisianasky I
Layson I
Gardner I
Two Brothers Rf.
French Frigate Sh.
Necker I
Bird I
Nihau (Tahura)
Kauai
Kauai I
Oahu I
Molokai I
Maui
Honolulu
Lahaina
Upolu Pt
Hawaii
Pohakoo
HAWAIIAN ISLANDS
Reed or Redfield Rks
San Francisco
Santa Cruz
Pt. Pinos
Aug. 26.
Aug. 31
Kingman Sh.
Palmyra I
Washington or New York I
Fanning I
Christmas I
Malden I
Starbuck I
Victoria I
Penrhyn
Vostok I
Caroline Atoll
Flint I
LINE ISLANDS
Admiralty Is
St. Matthias
New Hanover
New Mecklenburg
BISMARCK ARCHIPELAGO
PAPUA OR NEW GUINEA
Gulf of Papua
LOUISIADE ARCHIPELAGO
CORAL SEA
C. Flattery
New Pomerania
Bougainville I
Choiseul I
Lord Howe Is
Ontong Java Is
SOLOMON IS
Malaita
S. Cristobal
Guadalcanar
Rennell I
STA CRUZ IS
Sta Cruz I
Vanikoro
Torres Is
Banks Is
Espiritu Santo I
Aurora
Malliculo
Pentecost
Apt
Sandwich I
Eromango
Tanna
Erronan
Aneityum
NEW HEBRIDES
LOYALTY Is
CALEDONIA
Labou Rf
Penguin Bk
Pandora
Nukufetau
Funafuti
Nukulailai
Nurakita
Rotumah I
Ellice Is
Nanomea
Nui
Atafu
Nukunono
Fakaofu
UNION GROUP
Gente Hermosa I (Swain)
Danger Is
Nassau I
Rakahanga
Manahiki (Humphrey I)
Suvarov Is
SAMOAN OR NAVIGATOR IS
Savaii I
Upolu I
Tutuila I
Manua Is
Rose I
Ofu
Olosenga
Tafahi
Niuatobutabu (Keppel I)
Horne Is
Uea
FIJI ISLANDS
Vanua Levu
Niuafou
Vuna
Wai Lagi
Kandavu
Eastern Group
Lau
Lakemba
Oneata
Fanualai
Vavau
Lefuka
Tofoa
Hapai Group
Falcon I
Namuka Group
Vatoa
Ono I Lau Is
Tuvanai Thelo
FRIENDLY IS
Tongatabu
Niue (Savage I)
TONGA OR
Palmerston Is
Aitutaki
COOK ISLANDS
Takutea
Nitiero
Atiu
Mauki
Rarotonga
Mangaia
Duke of Gloucester Is
Nukuhiva
Uahuka
Hivaoa
Fatuhiva
MARQUESAS IS
Hatutu
Coral Is
Penrhyn
Bellingshausen
Mopeha
Borabora
Raiatea
Tetaroa
Tahiti
Moorea
SOCIETY ISLANDS
Maitea
Nukuhiva
Hiaroa
Two Groups
Harcheretue
Disappointment Is
Puka Puka
Pakaina
Rekareka
Amanu
Hao
Clermont Tonnerre
Nukutavake
Pinaki
TUAMOTU (PAUMOTU IS) OR LOW ARCHIPELAGO
Actaeon
S. Marutea
Moerenhout
Pangaiaufa
Morane
Peard
Mangareva Is
Timoe
Oeno
Henderson
Ducie
Pitcairn

MARINE DEPOSITS

"Albatross" Tropical Pacific Expedition 1899-1900

After Sir John Murray, K.C.B., LL.D., F.R.S.

Map 1A.



The Edinburgh Geographical Institute

Track of "Albatross" shown thus

J. G. Bartholomew.

OCEAN DEPTHS

Compiled from the latest sources 1901.

"Albatross" Tropical Pacific Expedition 1899-1900

Map I.ª

REFERENCE TO COLOURING

SEA LEVEL
100 Fathoms
500 "
1000 "
2000 "
3000 "
4000 "
5000 "

Ocean Soundings over 1,000 fathoms are shown by the first two figures only, thus 5,269 fathoms is represented by 52, the two last figures being omitted.

Tropic of Cancer

Equator

Tropic of Capricorn

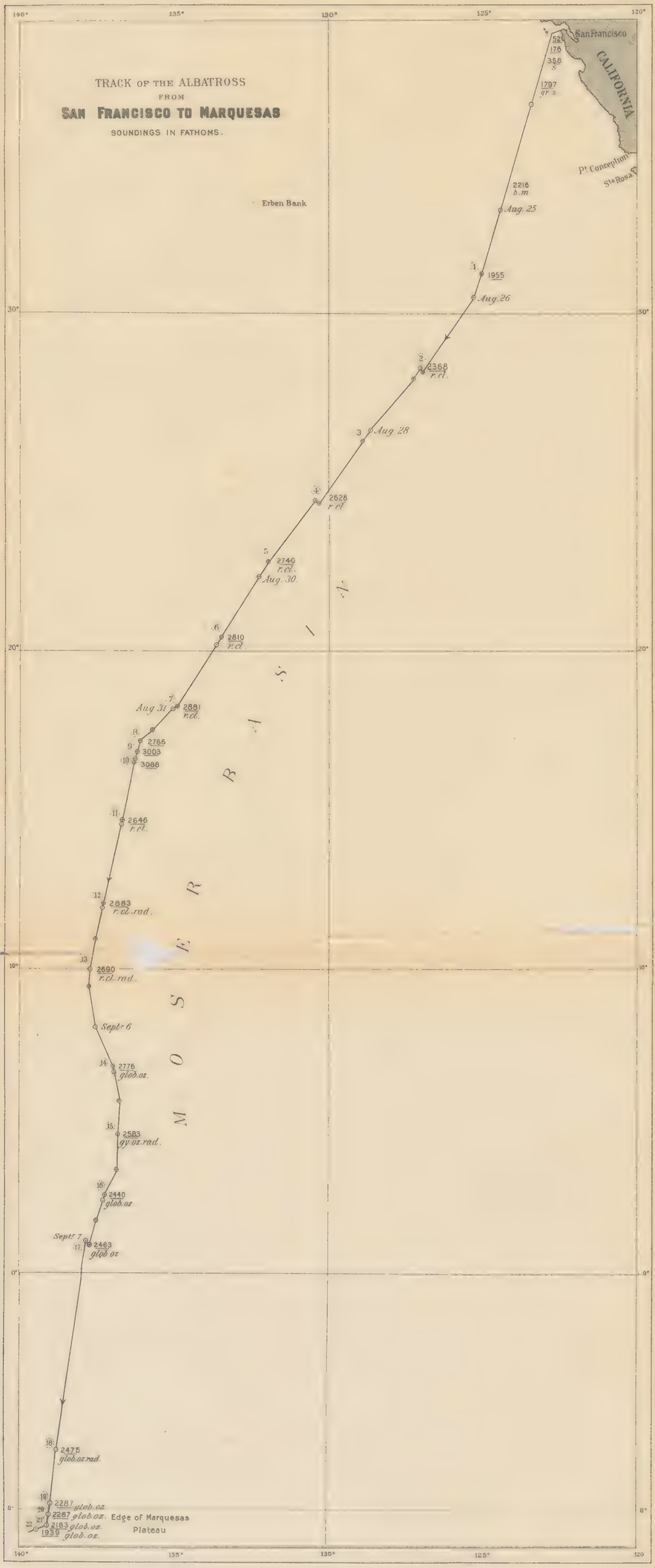
East of Greenwich

West of Greenwich

The Edinburgh Geographical Institute

Track of "Albatross" shown thus

J. G. Bartholomew


TRACK OF THE ALBATROSS
FROM
SAN FRANCISCO TO MARQUESAS
SOUNDINGS IN FATHOMS.
Erben Bank
San Francisco
CALIFORNIA
Pt Conception
Ste Rosa
524
176
358
s
1797
gr s
2216
b.m
Aug. 25
1
1955
Aug. 26
2
2368
r.cl.
3
Aug. 28
4
2628
r.cl
5
2740
r.cl.
Aug. 30.
6
2810
r.cl.
7
Aug 31
2881
r.cl.
8
2766
9
3003
10
3088
11
2646
r.cl.
12
2883
r.cl. rad.
13
2690
r.cl. rad.
Sept. 6
14
2776
glob. oz.
15
2583
gy. oz. rad.
16
2440
glob. oz
Sept. 7
17
2463
glob oz
18
2475
glob. oz rad.
19
2287
glob. oz
20
2267
glob. oz.
Edge of Marquesas
Plateau
21
2183
glob. oz.
22
1939
glob. oz.
SUPERBA
MOSER
140°
135°
130°
125°
120°
30°
20°
10°
0°
8°

TRACK OF THE ALBATROSS
THROUGH THE
MARQUESAS ISLANDS
SOUNDINGS IN FATHOMS.

141° 140° 139°

8°

9°

10°

Hatutu (Chanal.) (1380)

Eiao (Masse I.)

Coral I^s

s.mad

Clark Bk

19 2287 glob.oz.

20 2267 glob oz.

21 2183 glob oz volc part

22

23 1802 gl. glob oz rad volc part

1939 glob oz volc part

24 1040 glob.oz volc part

25 830 glob. vol. mud.

26

1173 Haunanu Pt glob.oz.plr.

Motu tabu

Washington I.
Ua Huka

Shaney B.

Hatiney B.

Hergest R^ks

Motuhi B

Hakapa B

Atupa atua

NUKUHIVA OR
MARCHAND I.

C. Martin

Anna Maria Bay

Chickakoff Pt

27 687 glob oz volc part.

28 1284 rocks

29 1932 glob.oz volc part

Anoau B.

Motupapai

Hakahau B

Adams I.
Ua pu

Akatau B.

Hoho i B

30 2456 glob. rad. volc. part.

C. Malatepai

Mautau Pt

C. Kiukiu

C. Balguerie

HIVA OA OR DOMINICA I.

C. Tehuhaiva

Bordelais Str.

Traitors B.

Ste Christina
Tau ata

San Pedro I.

Thomasset

Aimua Pt

Hanapano B

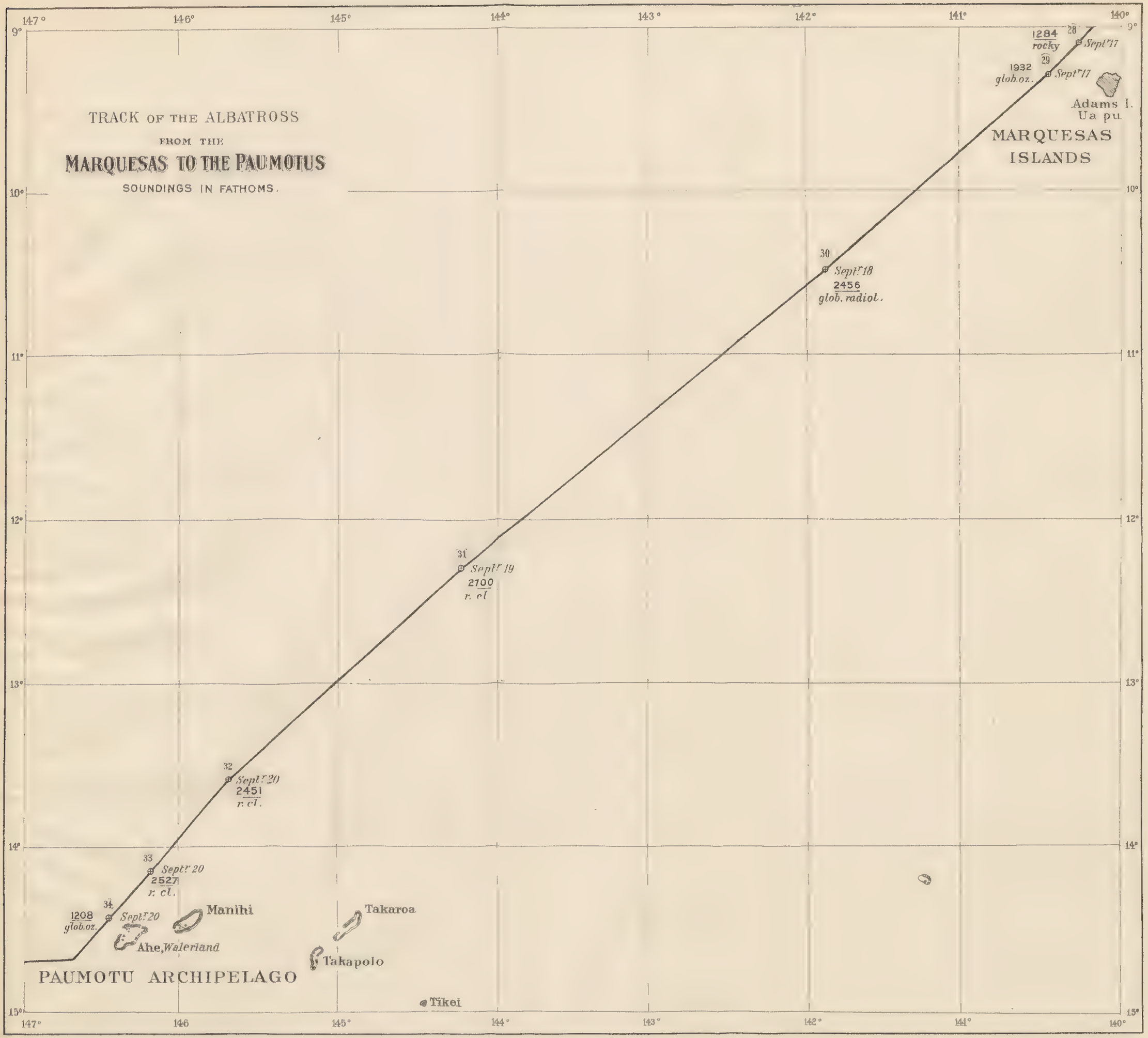
Magdalena I.
Fatu hiva

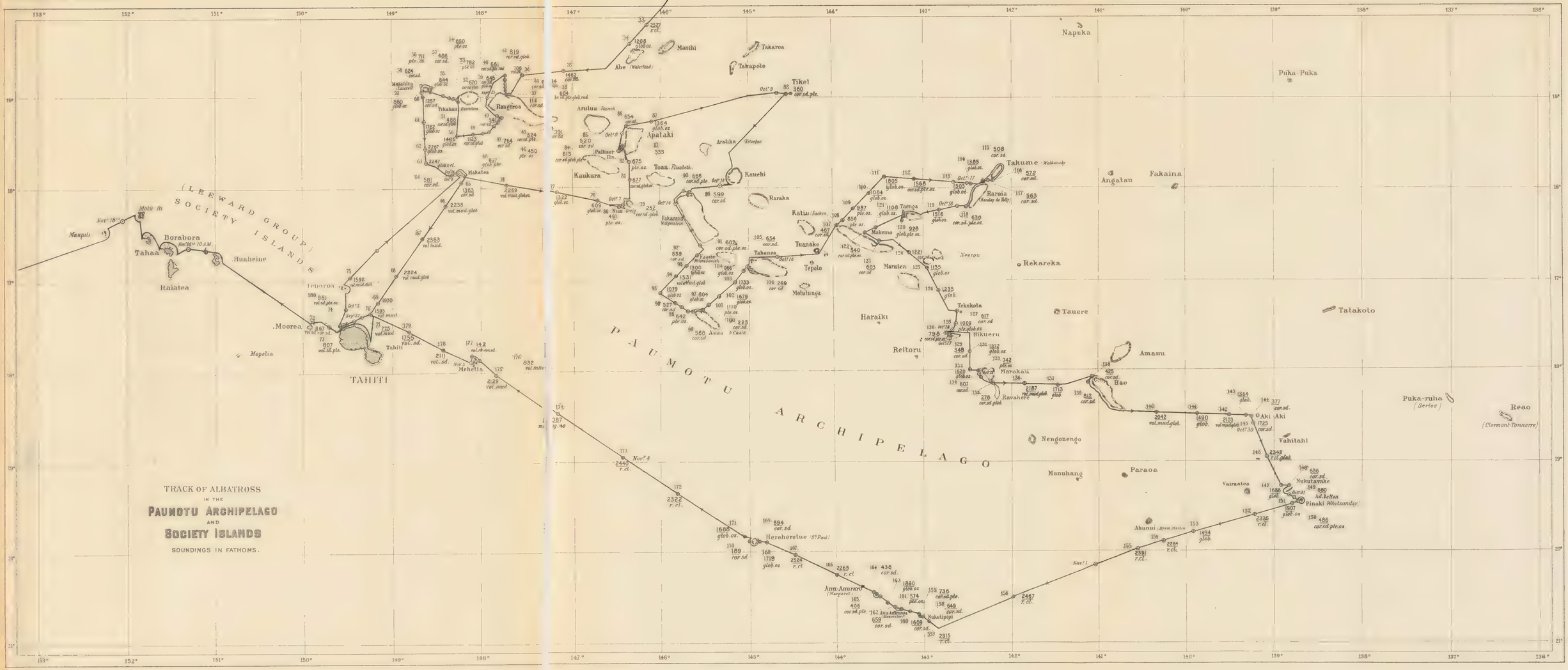
Hanamua

Mahiloa Pt

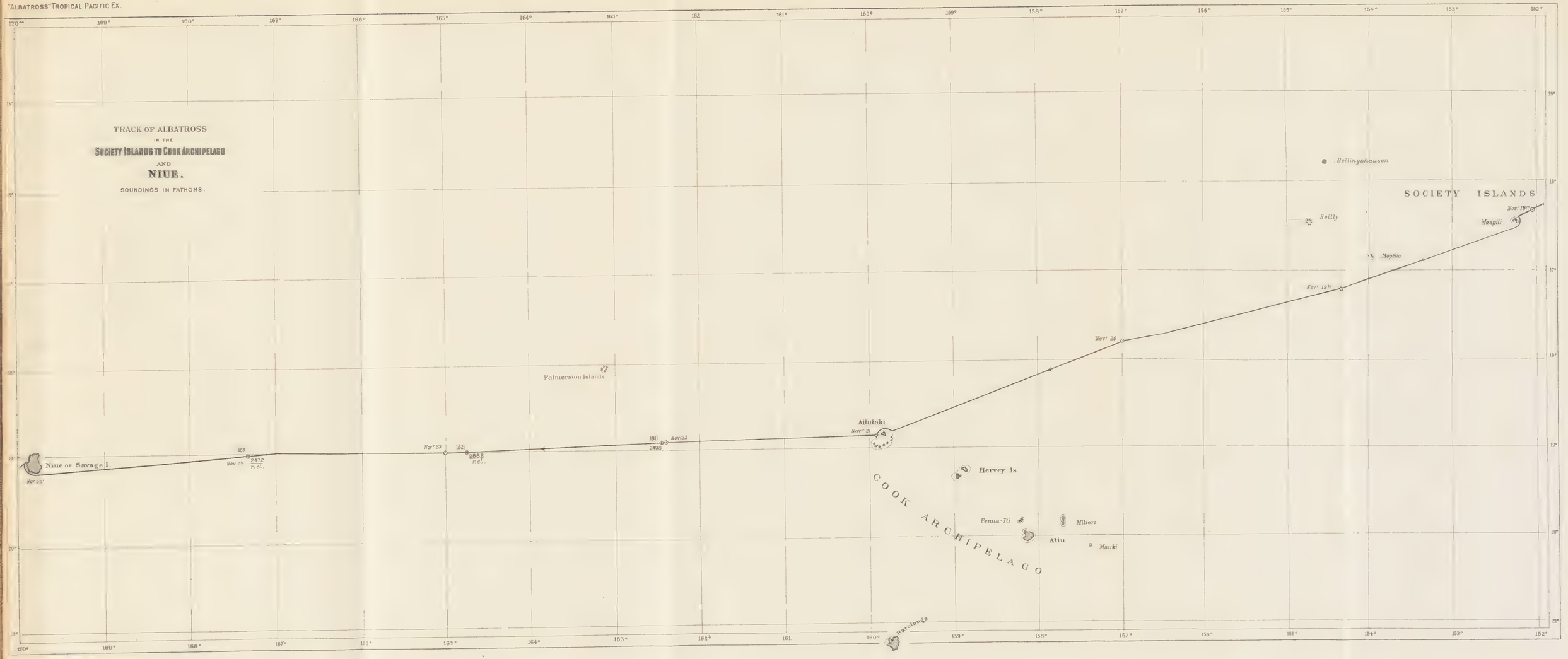
Teae Pt

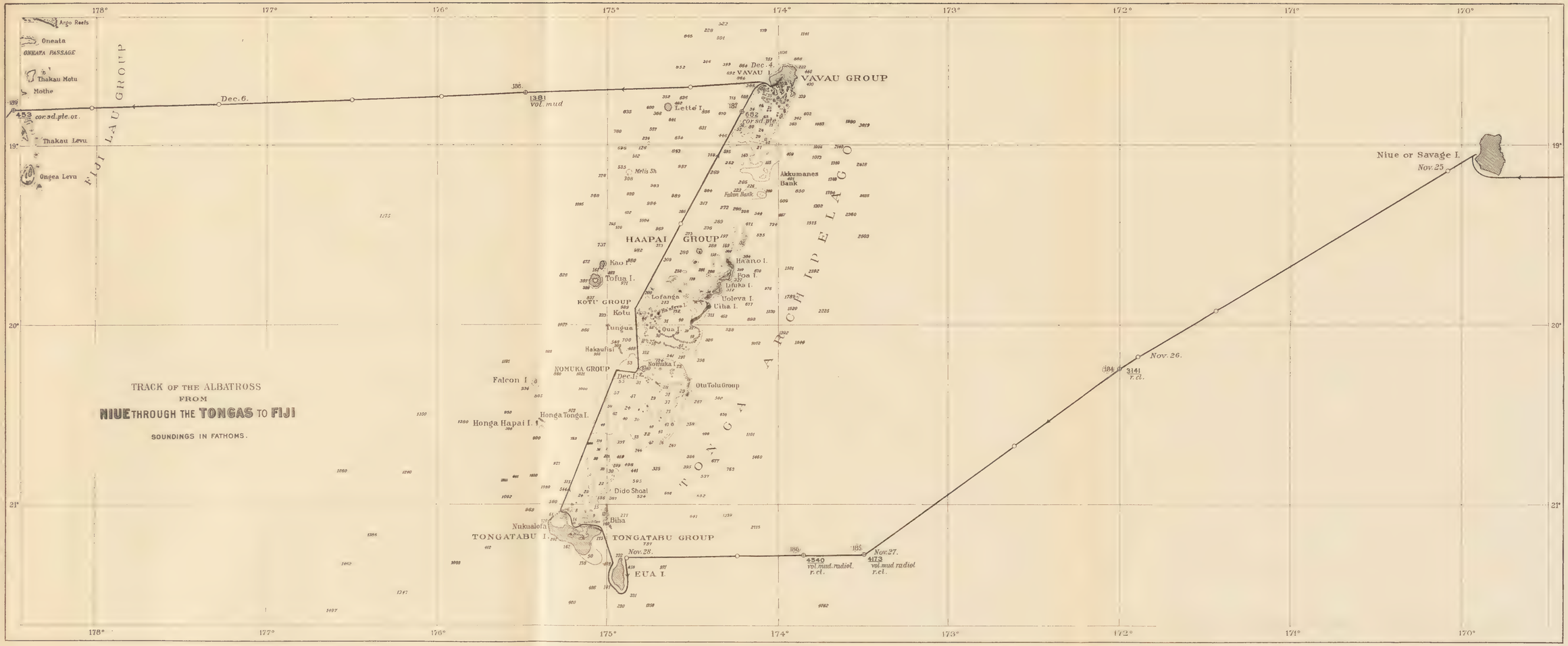
TRACK OF THE ALBATROSS
FROM THE
MARQUESAS TO THE PAUMOTUS
SOUNDINGS IN FATHOMS.





TRACK OF ALBATROSS
IN THE
PAUMOTU ARCHIPELAGO
AND
SOCIETY ISLANDS
SOUNDINGS IN FATHOMS.


TRACK OF ALBATROSS
IN THE
SOCIETY ISLANDS TO COOK ARCHIPELAGO
AND
NIUE.
SOUNDINGS IN FATHOMS.
SOCIETY ISLANDS
Bellingshausen
Scilly
Nov.r 18th
Manuili
Mopelia
Nov.r 19th
Nov.r 20
Palmerston Islands
Aitutaki
Nov.r 21
Nov.r 22
Nov.r 23
Niue or Savage I.
Nov.r 25th
Hervey Is.
COOK ARCHIPELAGO
Fenua-Iti
Miliero
Atiu
Mauki
Rarotonga
170°
169°
168°
167°
166°
165°
164°
163°
162
161°
160°
159°
158°
157°
156°
155°
154°
153°
152°

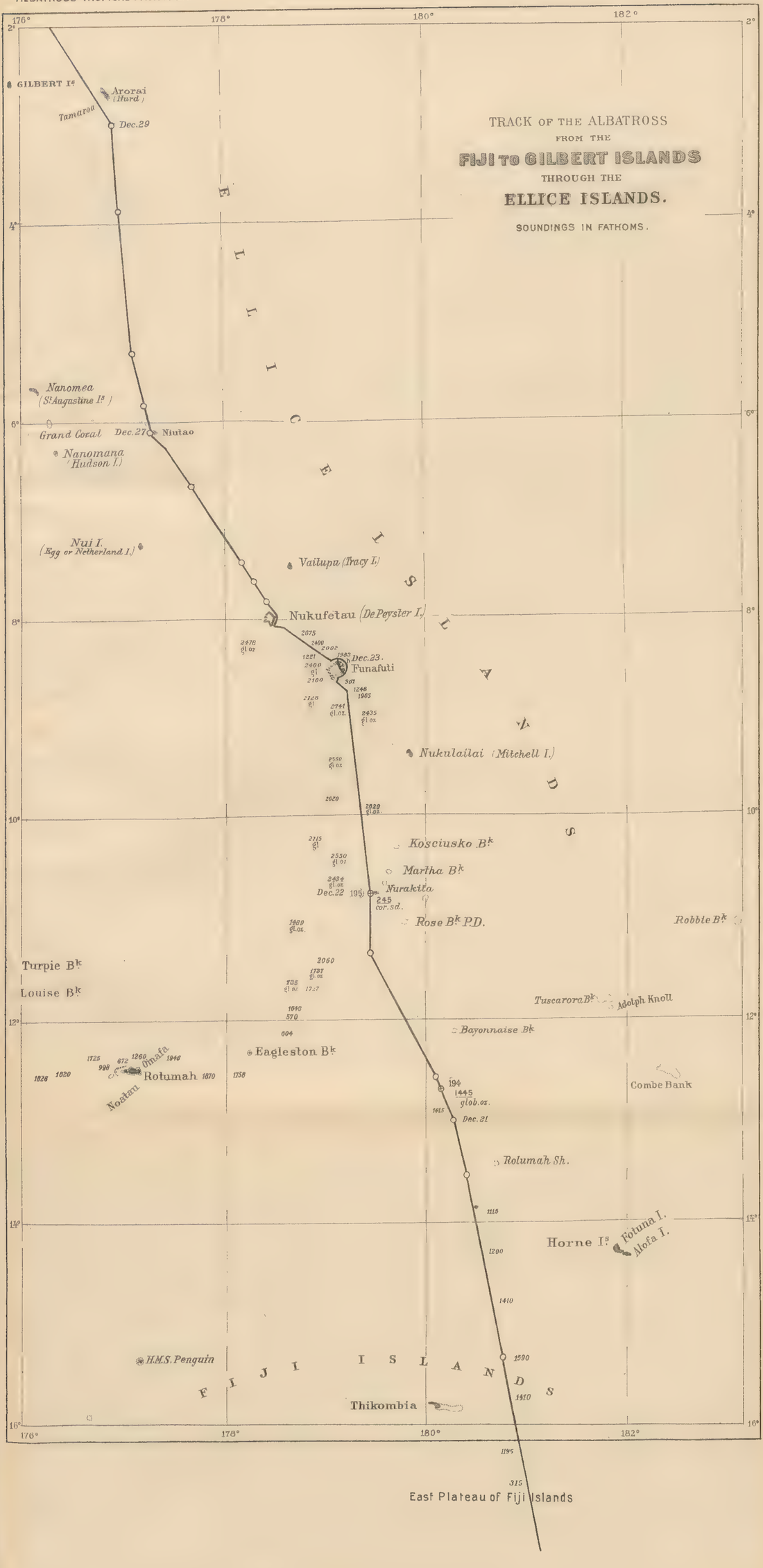


TRACK OF THE ALBATROSS
FROM
NIUE THROUGH THE **TONGAS** TO **FIJI**

SOUNDINGS IN FATHOMS.

TRACK OF THE ALBATROSS THROUGH THE FIJI ISLANDS

Thikombia
Vatanua
Ngele Levu
Dec.20
Cape Undu
Matathuthu
RINGGOLD ISLES
Adolphus Rf
Nuku Mbasanga
The Great Sea Reef
ROUND ISLAND PASSAGE
NATEVA BAY
VANUA LEVU
Ranibe I.
Budd Rf
Nanuku Rf
NAVU K. PASSAGE
Motua Levu
Motua Lailai
Wailangilala
Duff Reef
YASAWA GROUP
YASAWA (781)
Asawa ilau
NAVITI (740)
SOMO SOMO STRAIT
NGAMIA (1000)
NAVINI
Naitamba (610)
Kimbombo
Dibbles Rf.
Viwa I.
Charybdis Reef
Namena Barr Reef
Malima Is. (130)
Bell Rf.
YANUCA MBALAVU
KORO (1840)
Yathata
Kanathea (830)
EXPLORING ISLES
MAMANUTHA ISLANDS
Makongai (876)
Vatu Vara (1050)
Mango I (670)
Malevuvu Reef
Katafanga
Bar R.
VITI LEVU
OVALAU
Horse Shoe Reef
KORO
Tuvutha (800)
Vekai I. (90)
Thakau Tambu
Mbatiki (609)
Nairai (1104)
Thithia (540)
Thakau Lasemarawa
LAKEMBA PASSAGE OR EASTERN PASSAGE
Reid Reef
Naiau (580)
NGAU
SEA
Dec.19
Lakemba (720)
Reefs
Ajwa (610)
Vanua Vatu (310)
Oneata (160)
ONEATA PASSAGE
Thakau Lekaleka
Mothe (600)
Olorua
Komo (270)
Thakau Moru
Vatu Leile (110)
Mbengha (1456)
North Astrolabe Reef
KANDAVU PASSAGE
MOALA (1535)
Tova
Tavunasilu (200)
FULANGA PASSAGE
Namuka (660)
189 453 cor sd pte of
Wangava
193 990 cor. sd.
Dec.7
Thakau Levu
Great Astrolabe Reef
KANDAVU
Totova (1062)
Kambara (470)
Marambo
Yangasa Cluster
190 324 cor sd
191 600 pte of
192 450 cor sd
Fulanga (260)
Ongea Levu (270)
Matuku (1262)
FIJI ISLANDS
Continuation of Group to Southward.
Vatoa or Turtle I. (209)
Onoilaw (370)
Simonoff (95)
Vatoa or Turtle I. (209)
ALLA.
SOUNDINGS IN FATHOMS.


TRACK OF THE ALBATROSS
FROM THE
FIJI TO GILBERT ISLANDS
THROUGH THE
ELLICE ISLANDS.
SOUNDINGS IN FATHOMS.
GILBERT Is
Arorai (Hurd)
Tamaroa
Dec. 29
Nanomea (St Augustine Is)
Grand Coral
Dec. 27
Niutao
Nanomana (Hudson I.)
Nui I. (Egg or Netherland I.)
Vailupu (Tracy I.)
Nukufetau (DePeyster I.)
Dec. 23.
Funafuti
Nukulailai (Mitchell I.)
Kosciusko Bk
Martha Bk
Dec. 22
Nurakita
245 cor. sd.
Rose Bk P.D.
Robbie Bk
Turpie Bk
Louise Bk
Tuscarora Bk
Adolph Knoll
Bayonnaise Bk
Eagleston Bk
Rotumah
Oinafa
Noatau
Combe Bank
Dec. 21
Rolumah Sh.
Horne Is
Fotuna I.
Alofa I.
H.M.S. Penguin
FIJI ISLANDS
Thikombia
East Plateau of Fiji Islands

TRACK OF THE ALBATROSS THROUGH THE GILBERT ISLANDS

SOUNDINGS IN FATHOMS.

GILBERT ISLANDS

172° 173° 174° 175° 176° 177°

4° 3° 2° 1° 0° 1° 2° 3°

208
2486
glob.oz.

Jan. 7

Makin I.
(Pitt I.)

Taritari
(Touching I.)

Jan 5

207
1461
glob.oz.

206
2255
globoz

205
431
cor.sd.

Maraki
(Matthew I.)

204
2156
glob.oz.

Apaiang
(Charlotte I.)

Jan. 4

203
170

Tarawa
(Cook I.)

202
1569
globig

200
95
bro.sh.

199
413
glob.oz

201
200

Maiana
(Hall I.)

Jan 2

Jan. 2 1900

198
1365
glob.oz.

197
2221
glob.oz.

Apamama
Hopper I

Jan. 1

196
170
hard bott.

Kuria

Aranuka
(Henderville I.)

Nonuti
Sydenham I.

Dec. 31

Taputeuea
(Drummond I.)

Peru
(Francis I.)

Nukunau
(Byron I.)

Onoatoa
(Clerk I.)

Dec. 31

Tamana
(Rotcher)

Arorai
Hurd

Dec. 29-99

TRACK OF THE ALBATROSS
THROUGH THE
MARSHALL ISLANDS
AND TO
PONAPI, (CAROLINES.)

SOUNDINGS IN FATHOMS.

M A R S H A L L I S L A N D S

C A R O L I N E I S L A N D S

Taongi
Smyth or Gaspar Rico Atoll

Bikar or Dawson Atoll

Eniwetok or Brown Atoll

Bikini or Eschholtz Atoll

Rongelab Atoll

Rongerik Atoll

Utirik or Katusov I.

Taka or Suvarov

Ailinginae Atoll

Ailuk or Tindal & Watts Atoll

Mejit Atoll

Jemo I.

Likieb Atoll

Wotho or Schanz Atoll

Ujelang, Arecifos or Providence Atoll

Wotje or Romanzov Atoll

Kwajalong or Menschikov Atoll

Ujae or Katharine Atoll

Lae Atoll

Erikub

Maloelab Kaven or Calvert Atoll

Aurh or Ibbetson Atoll

Lib I.

Namu or Musquillo Atoll

Elmore or Odia Atoll

Majuro or Arrowsmith Atoll

Arhno Atoll

Ponapi or Puynepet I. *(Seniavina I.)*

Kill Harbor

Mokil or Duperrey I.

Pingelap or Macaskill I.

Kusaie or Ualan I.

P. Lottin

Chabrol

Namorik or Baring Atoll

Jaluit or Bonham Atoll

Mille or Mulgrave Atoll

Knox I.

Keals Bank

Kili or Hunter I.

Ebon or Boston Atoll

TRACK OF THE ALBATROSS
FROM STATION 240 WEST OF PONAPI
THROUGH THE
CAROLINES TO GUAM
SOUNDINGS IN FATHOMS.

Feb 25 — Rota I. — 4618 — 3014 — 1903 — 2259 — 3154

Feb. 21 — Pt Lafjas — Port St Luis d'Apra — Guam or Guajan I. — 3461 — 1606 — 1137 — Pt Eacpi — Tarofofo Pt

249 — 2026 — 2337 vol. sd. — 4560 — 3057

Galvez Bk. — Reef P.D. — St Rosa Reef

248 — 5260 — 4813 vol. part.

NERO DEEP

247 — 3213 r. cl.

246 — 2993 r. cl.

245 — 2735 r. cl.

Grimes I. — Mc Laughlin Bk

Magur — Feb. 18 — Unalik — Namonuito Is — Ulul — Pisaras I.

Faraulep — Pikela or Lydia — East Faiu — Morileu Is — Namolipiafane Is — HALL Is

Dunkin R.f RD

Pikelot or Coquille I. — Oraitilipu — Gray Feather Bk — Earl Dalhousie — West Faiu

244 — 2205 glob. mud.

Minto R.f PD

Olimarao — Pis I. — Feb. 14 — Moet — Tol I. — TRUK OR HOGOLU Is

Los Martires — Panadik — Elato — Lamotrek — Toass — Satawal or Tucker I. — Enderby Is — Uranie — Wolea or Ulie Is — Ifalik or Wilson Is

Reported 1886 — Suzanne Rf. — Royalist Is — L'Urville I.

243 — 2162 glob. mud. — Losap I. — 242 — 526 cor. sd. — 241 — 2533 glob. mud. vol. mud. — 240 — Feb. 13 — 2475 glob. vol. mud.

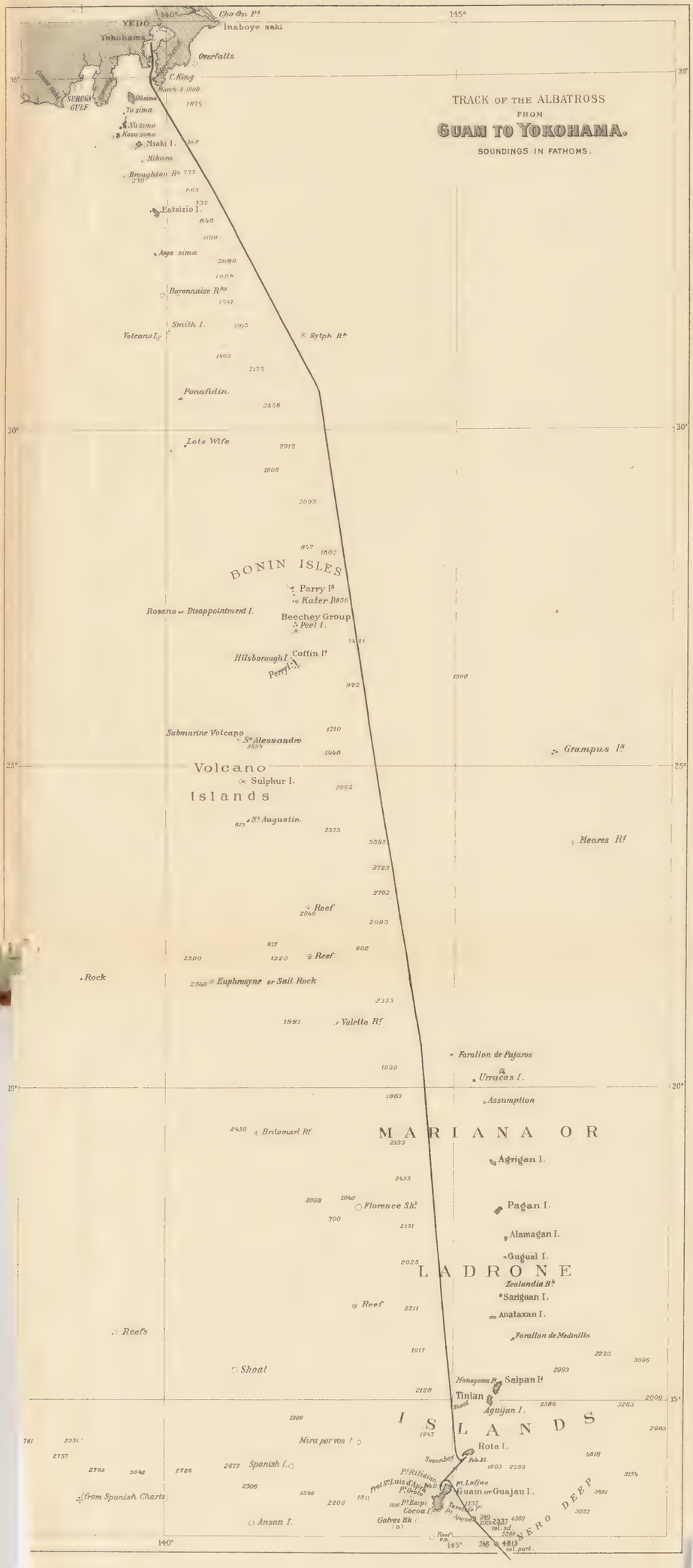
St Augustin — Oraluk or Bordelaise — Amicitia I.m

Suk or Pulusuk — Paz Bank — Lady Elgin Bk

Lanthe Shoal P. D. — Nile Shoal P. D. — Helene Shoal — Namoluk — Lukunor — Unepuk — Mortlock Is — Nukuor or Monteverde

144° 145 146° 147° 148° 149° 150° 151° 152° 153° 154° 155° 156° 157°

14° 13° 12° 11° 10° 9° 8° 7° 6° 5° 4°


TRACK OF THE ALBATROSS
FROM
GUAM TO YOKOHAMA.
SOUNDINGS IN FATHOMS.
YEDO
Yokohama
Inaboye saki
Cho-Osi Pt
Overfalls
C. King
March 4 1900
1875
SURUGA GULF
Osima
To sima
Nii sima
Kosu sima
Miaki I.
Mikura
Broughton Rk
Eatsizio I.
Aoga sima
Bayonnaise Rks
Smith I.
Volcano I.
Sytph Rk
Ponafidin
Lots Wife
BONIN ISLES
Parry Is
Kater I. 1856
Rosario or Disappointment I.
Beechey Group
Peel I.
Coffin Is
Hilsborough I.
Perry I.
Submarine Volcano
St Alessandro
Grampus Is
Volcano
Islands
Sulphur I.
St Augustin
Meares Rf
Reef
Rock
Euphrosyne or Sail Rock
Valetta Rf
Farallon de Pajaros
Urracas I.
Assumption
Brilomart Rf
MARIANA OR
Agrigan I.
Pagan I.
Florence Sh
Alamagan I.
Guguai I.
LADRONE
Zealandia Bk
Sariguan I.
Reef
Anataxan I.
Reefs
Farallon de Medinilla
Shoal
Managasse Rf
Saipan I
Tinian
Aguijan I.
ISLANDS
Mira por vos ?
Rota I.
Spanish I.
(from Spanish Charts)
Anson I.
Sugombey
Pt Rifidian
Pt Luis d'Apra
Pt Orote
Pt Lafiae
Guam or Guajau I.
Pt Encpi
Cocoa I
Galvez Bk
Reef
MARIANA DEEP
140°
145°
35°
30°
25°
20°
15°

"ALBATROSS" TROPICAL PACIFIC EX.

PLATE 14.

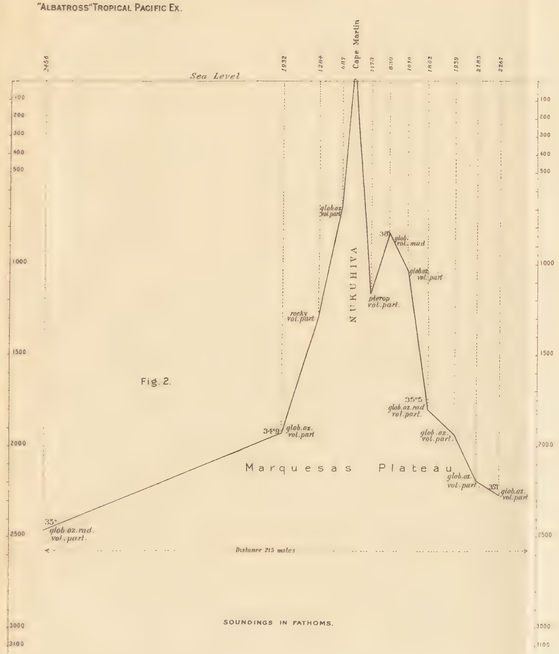


Fig. 2.

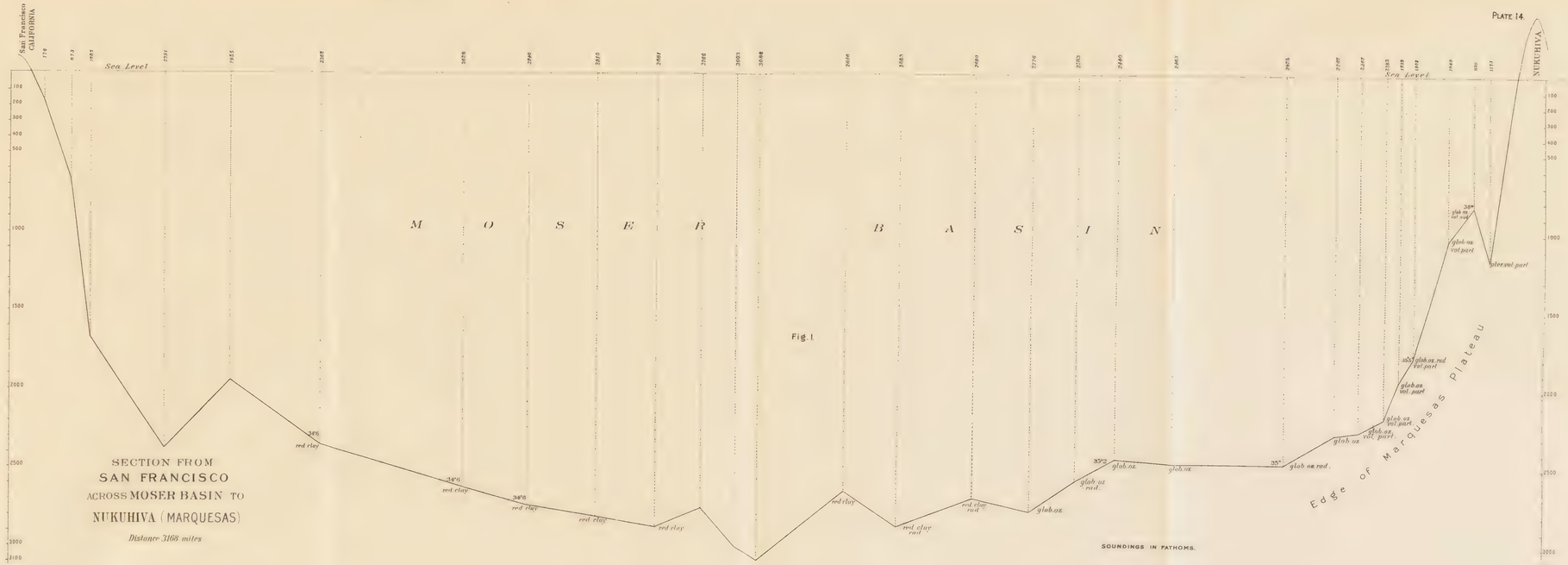


Fig. 1.

SECTION FROM
SAN FRANCISCO
ACROSS MOSER BASIN TO
NUKUHIVA (MARQUESAS)
Distance 3165 miles

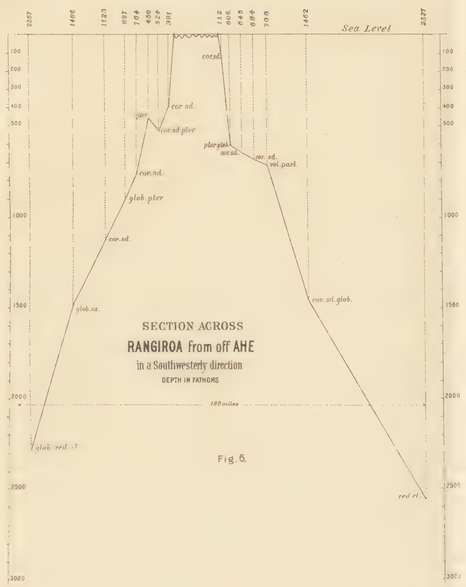


Fig. 6.

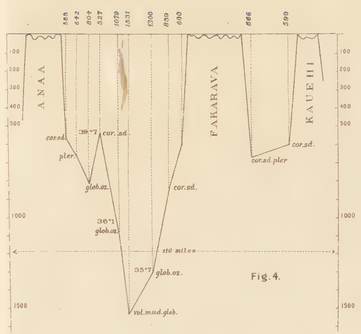


Fig. 4.

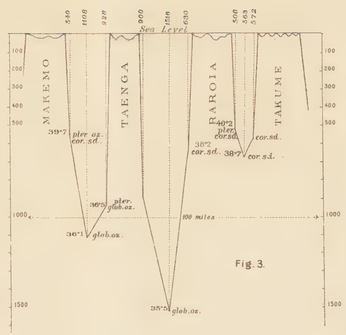


Fig. 3.

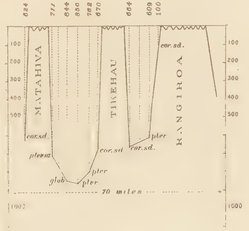


Fig 5.

SOUNDINGS IN FATHOMS.

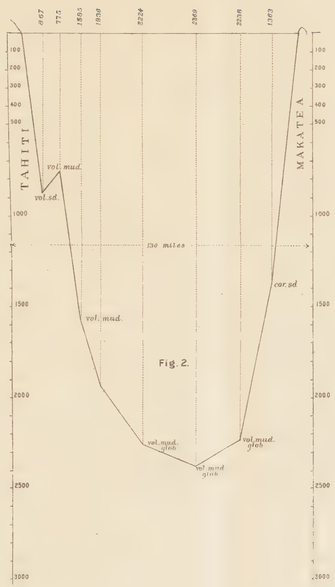


Fig. 2.

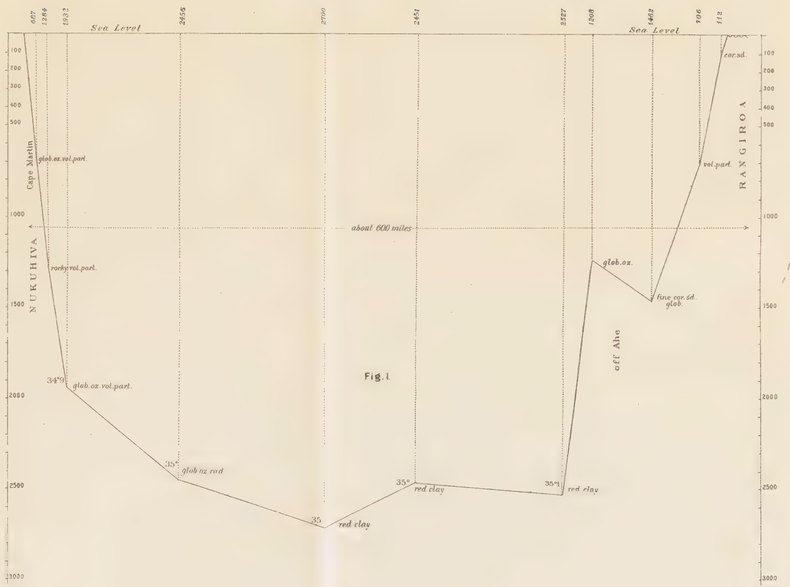


Fig. 1.

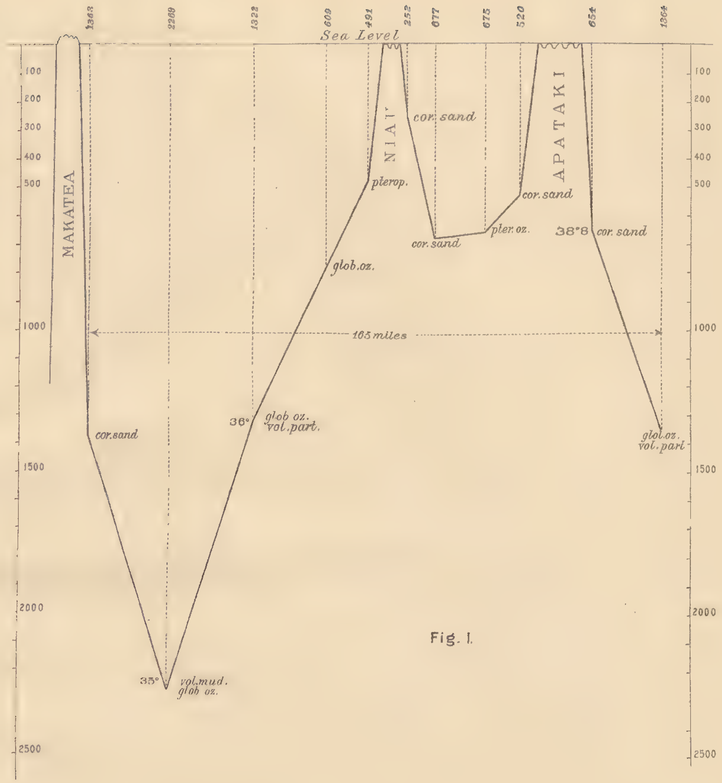


Fig. 1.

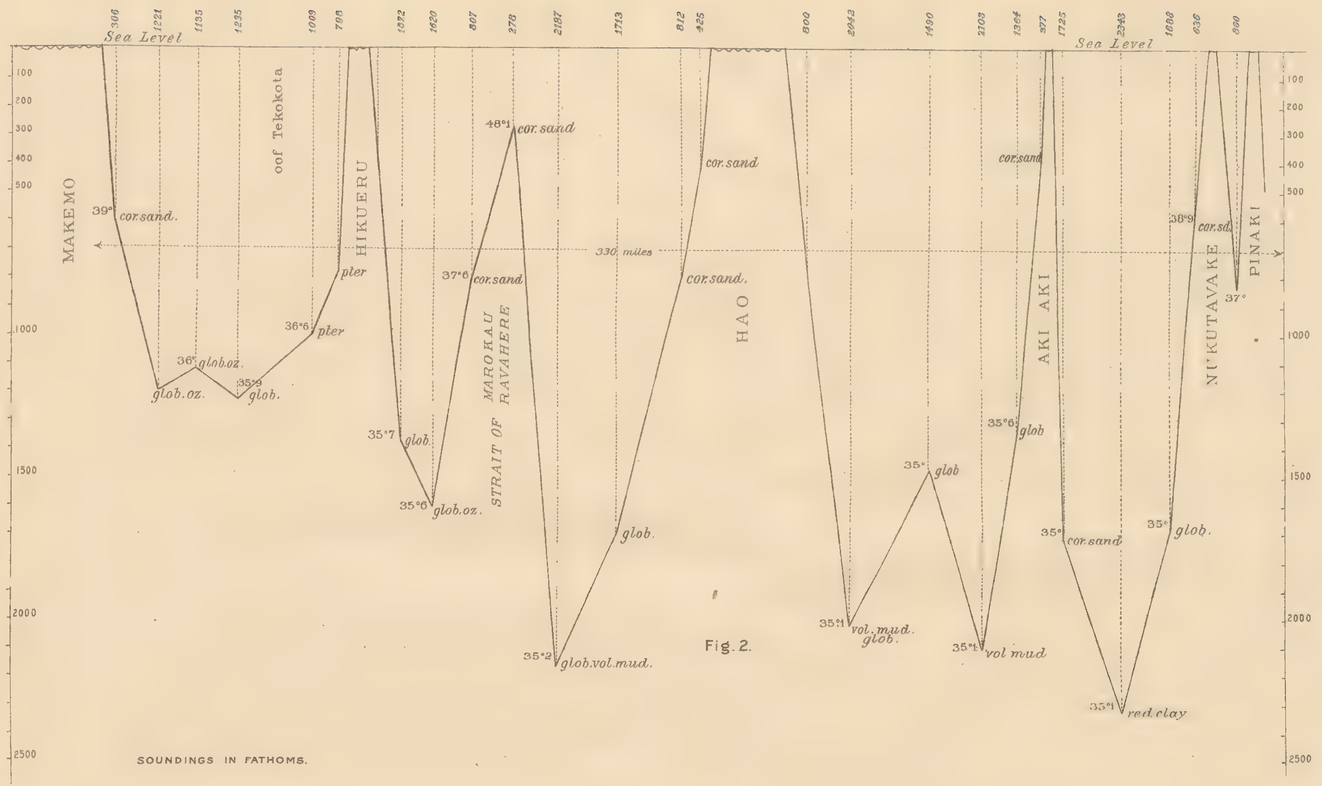
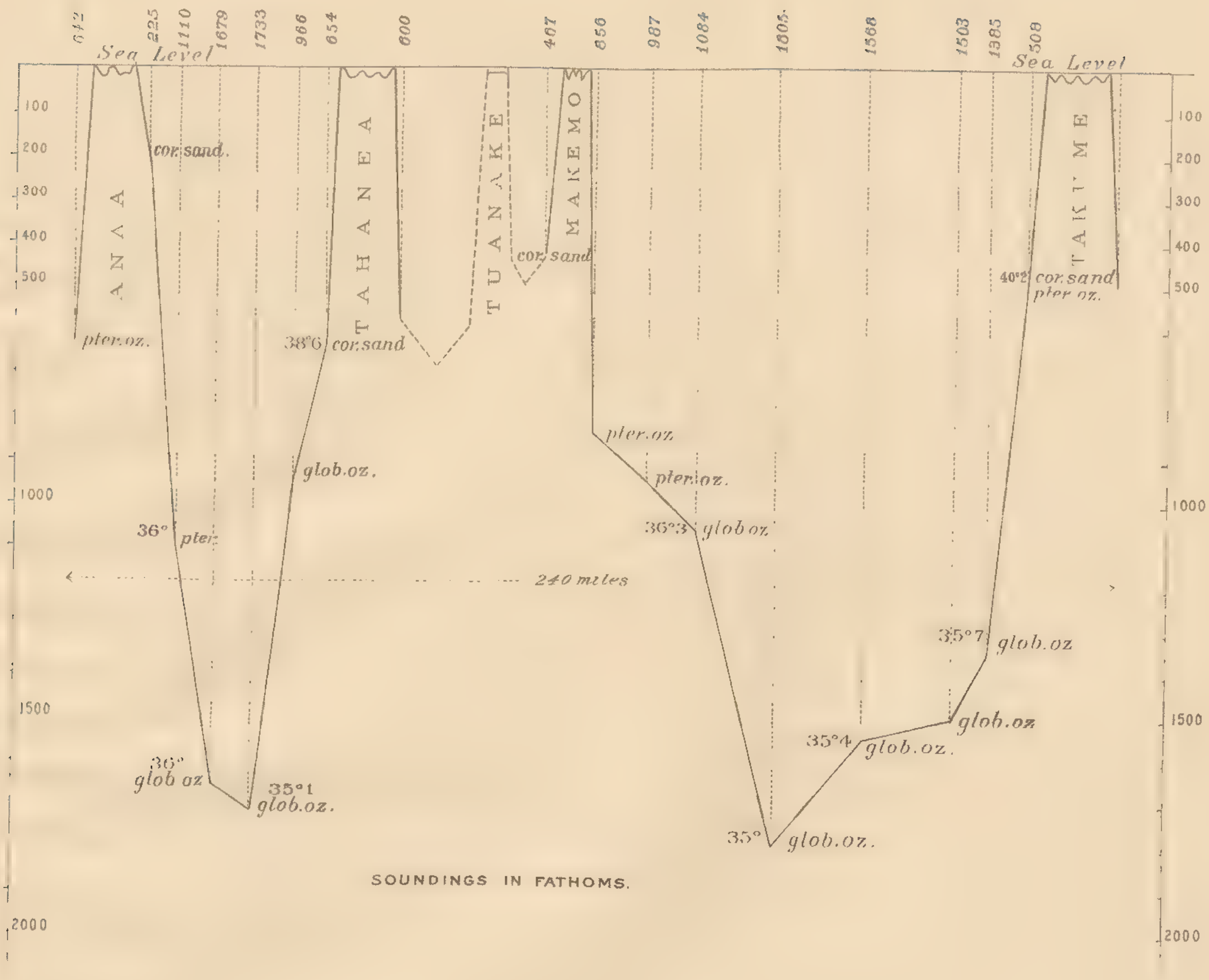


Fig. 2.

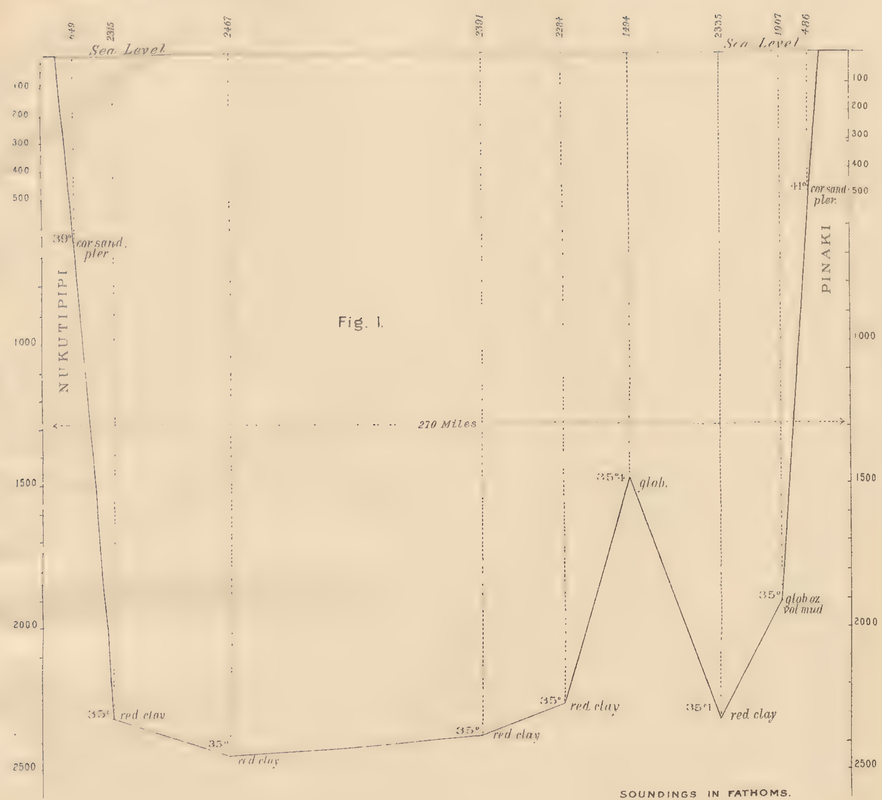
SOUNDINGS IN FATHOMS.

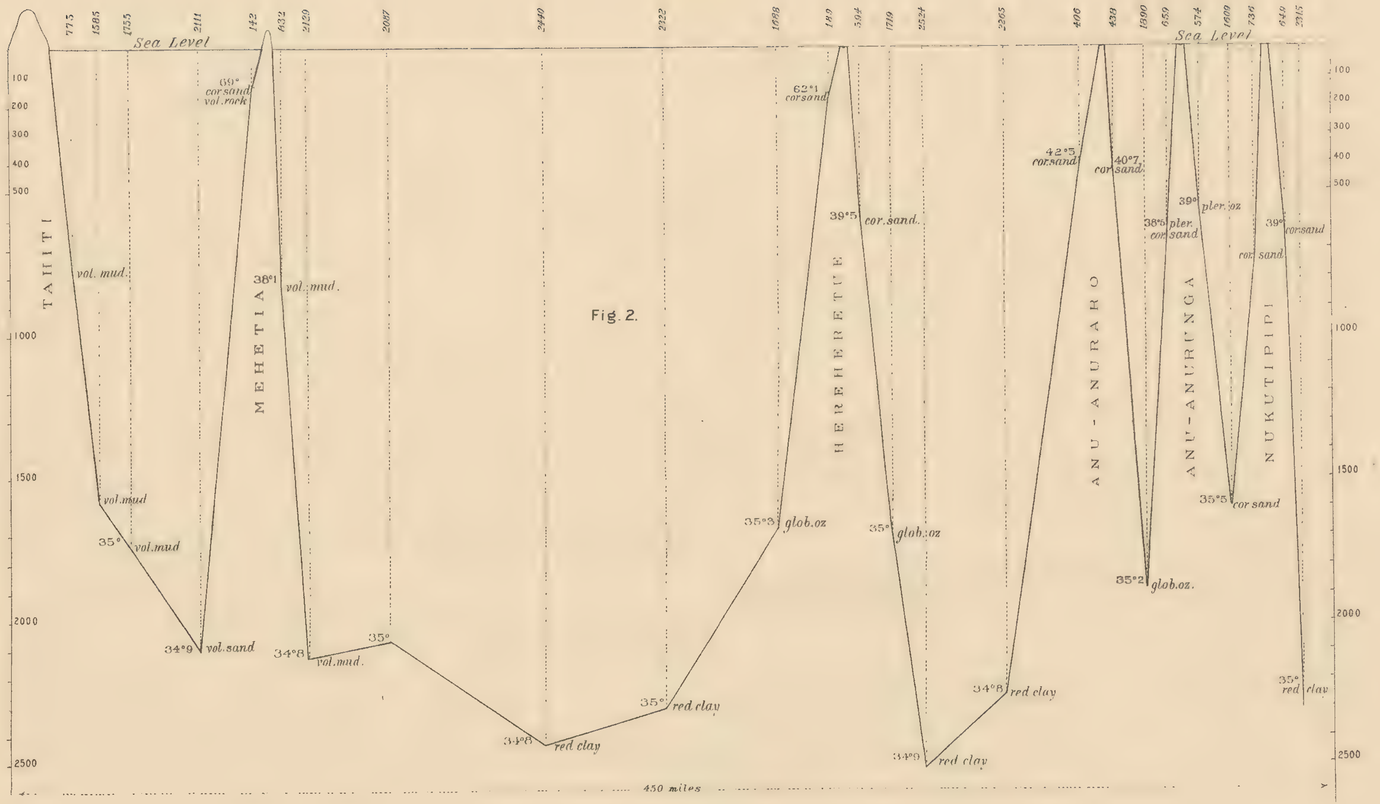


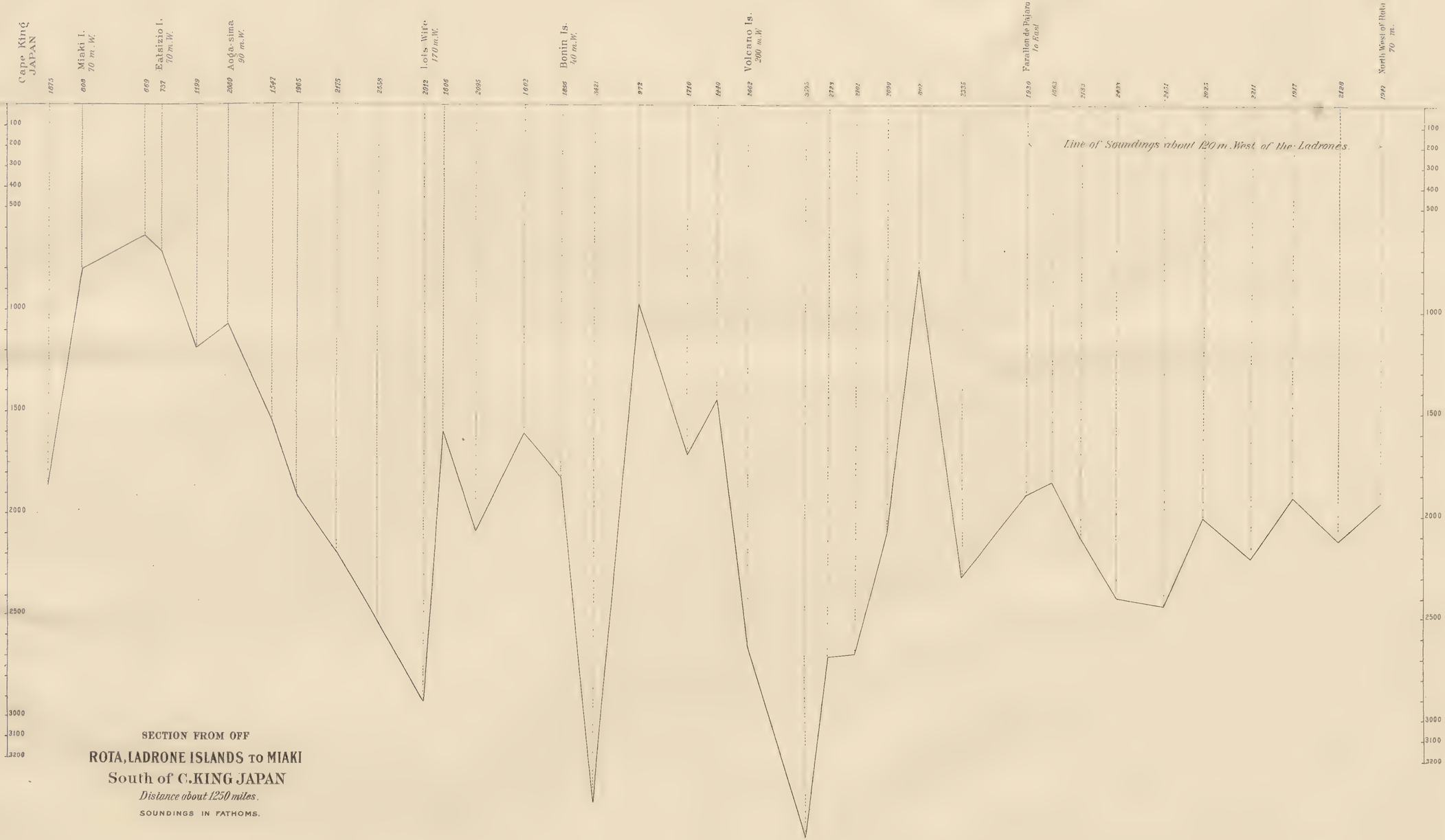
SOUNDINGS IN FATHOMS.

"ALBATROSS" TROPICAL PACIFIC EX.

PLATE 18.







SECTION FROM OFF

ROTA, LADRONE ISLANDS TO MIAKI

South of C. KING JAPAN

Distance about 1250 miles.

SOUNDINGS IN FATHOMS.

PUBLICATIONS

OF THE

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There have been published of the BULLETIN Vols. I. to XXXVII.; of the MEMOIRS, Vols. I. to XXIV.

Vols. XXXVIII., XXXIX., and XL. of the BULLETIN, and Vols. XXV., XXVI., and XXVII. of the MEMOIRS, are now in course of publication.

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